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The Biological Effects of Electromagnetic Radiation serves as a vehicle through which current documentation of research highlights on the biological effects and health implications of nonionizing electromagnetic radiation (microwave and radio-frequency radiation) are compiled, condensed, and disseminated on a regular basis. BEEMR is intended to be a highly useful current awareness tool for scientists engaged in research or related activities, the great number and diversity of relevant publications make imperative the availability of this service to persons whose work requires that they keep abreast of current developments in the field.

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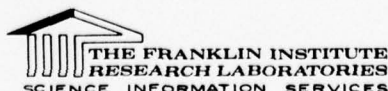
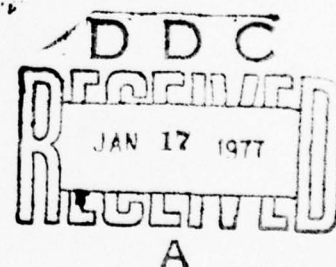
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# BIOLOGICAL EFFECTS OF ELECTROMAGNETIC RADIATION

A Digest of Current Literature and a  
Forum of Communication

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Literature Selected and Abstracted  
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Bruce H. Kleinstein, Ph.D., Technical Editor

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## PREFACE

*Biological Effects of Electromagnetic Radiation* is a publication researched and prepared by the Franklin Institute Research Laboratories, Science Information Services Department, under a grant from the U.S. Army Research Office. The grant is co-sponsored by the Bureau of Radiological Health, Food and Drug Administration; Office of Naval Research; U.S. Navy Bureau of Medicine and Surgery; U.S. Air Force School of Aerospace Medicine; and the Walter Reed Army Institute of Research. The U.S. Environmental Protection Agency is cooperating in this project.

This digest serves as a vehicle through which current documentation of research highlights on the biological effects and health implications of nonionizing electromagnetic radiation (microwave and radiofrequency radiation) are compiled, condensed and disseminated on a regular basis. *Biological Effects of Electromagnetic Radiation* is intended to be a highly useful current awareness tool for scientists engaged in research or related activities. The great number and diversity of relevant publications make imperative the availability of this service to persons whose work requires that they keep abreast of current developments in the field.

*Biological Effects of Electromagnetic Radiation* is published quarterly. The issues of Volume II, and future volumes, will include materials received during the preceding three months. Each issue will include news items and announcements, a listing of meetings and conferences, abstracts of current literature, and a directory of current research. Materials for which full text is not available will be included as citations. When available, a special report section, technical note, book review, or topical retrospective literature survey will be included.

## ABBREVIATIONS AND ACRONYMS

### - A -

A, amp - ampere  
A - angstrom  
AC - alternating current  
ACTH - adrenocorticotrophic hormone  
AF - Air Force  
AMP - adenosine monophosphate  
ANSI - American National Standards Institute  
ATP - adenosine triphosphate

### - B -

BRH - Bureau of Radiological Health

### - C -

c - cyclic  
C - Centigrade  
Ci - Curie  
CL - Current Literature  
cm - centimeter  
CNS - central nervous system  
cps - cycles per second  
CR - Current Research  
CW - continuous wave

### - D -

dB - decibel  
dc - direct current  
DNA - deoxyribonucleic acid  
DOD - Department of Defense  
DOPA - dihydroxyphenylalanine

### - E -

E,  $\hat{E}$  - electric field  
ECG - electrocardiogram  
EEG - electroencephalogram  
EHF - extremely high frequency  
ELF - extremely low frequency  
EM - electromagnetic  
EMC - electromagnetic compatibility  
EMF - electromagnetic field  
EMI - electromagnetic interference  
EMP - electromagnetic pulse  
EMR - electromagnetic radiation  
EPA - Environmental Protection Agency  
ES - electrostatic  
ELS - electrostatic field

### - F -

f - frequency  
F - farad  
FDA - Food and Drug Administration

### - G -

g - gram  
G - Gauss  
GHz - gigahertz

### - H -

H,  $\hat{H}$  - magnetic field  
HEW, DHEW - Department of Health, Education, and Welfare  
HF - high frequency

hr - hour  
Hz - hertz

### - I -

IEEE - Institute of Electronic and Electrical Engineers  
IMPI - International Microwave Power Institute  
i.p. - intraperitoneal  
IR - infrared  
i.v. - intravenous

### - J -

J - joule

### - K -

kA - kiloampere  
kg - kilogram  
kHz - kilohertz  
km - kilometer  
kV - kilovolt  
kW - kilowatt

### - L -

l - liter  
lb - pound  
LD<sub>50</sub> - 50% mortality  
LF - low frequency

### - M -

m - meter  
mA - milliamper  
mc - megacycle  
mg - milligram  
mho - unit of measurement of conductivity  
MHz - megahertz  
min - minute  
ml - milliliter  
mm - millimeter  
mmho - millimho  
mOe - millioersted  
mon - month  
mW - milliwatt  
Mw - megawatt  
MW - microwave  
mV - millivolt

### - N -

NBS - National Bureau of Standards  
NIH - National Institutes of Health  
NIOSH - National Institute for Occupational Health and Safety  
nm - nanometer  
NSF - National Science Foundation

### - O -

Oe - oersted  
ONR - Office of Naval Research  
OSHA - Occupational Safety and Health Administration

### - P -

PFd - power flux density  
PHS - Public Health Service



## ABBREVIATIONS AND ACRONYMS

*Biological Effects Electromagnetic  
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p.o. - orally  
pps - pulses per second  
PRF - pulse repetition frequency  
PW - pulsed wave

### - R -R

R, rad - Roentgen  
RF - radiofrequency  
RNA - ribonucleic acid

### - S -

s.c. - subcutaneous  
sec - second  
SHF - super high frequency  
Sq - solar quiet daily variation  
SW - shortwave

### - T -

TLV - threshold limit value

### - U -

UHF - ultrahigh frequency  
US - ultrasound  
USDA - U.S. Department of Agriculture  
USNC - URSI - International Union of Radio Science -  
U.S. National Committee  
UV - ultraviolet

### - V -

V - volt  
VA - Veterans Administration  
VLF - very low frequency  
vol - volume

### - W -

W - watt  
WBC - white blood cell  
WG - waveguide  
WHO - World Health Organization  
wk - week  
wt - weight

### - Y -

yr - year

## SYMBOLS

$\epsilon$  - dielectric constant  
 $\hat{\epsilon}$  - complex permittivity  
 $\lambda$  - wavelength  
 $\mu$  - micro  
 $\sigma$  - specific conductance  
 $\gamma$  - gamma  
 $\Omega$  - ohm

## NEWS ITEMS

### HIGH VOLTAGE POWER LINE CONTROVERSY

There is controversy concerning ultra high voltage power lines as a source of electrical emissions which might be dangerous to humans and animals. The U.S. Environmental Protection Agency's radiation division is investigating the limiting of such lines or imposing special precautions on public exposure. The Soviet Union did find some adverse physiological effects among workers on lines below the ultrahigh voltage level. Exposure limits were set there in 1971 after some workers showed 'instability' of pulse and blood pressure and tremors of arms and legs. Two proposed power lines in northern New York State and another in Michigan are presently under controversy. The ultra powerful lines carry 765,000 V and have noise levels up to 60 dB. The electric field around lines causes shock if a metal surface, such as a vehicle side, is touched. The lines carry alternating current, oscillating at the standard rate of 60 Hz. It is these fluctuations, combined with the strength of the current, that are thought to have harmful physiological effects. Nearly all the ultra high lines in the U.S., in Virginia, West Virginia, Ohio, Kentucky, Indiana, and Michigan, belong to the American Electric Power Co. The lines run from major generating plants to electric companies' distributing centers. There, the current is reduced in steps to the 110 V and 220 V levels. Transmission is progressively less expensive as voltage is stepped up. The power industry claims that by using high voltage lines, the number of lines needed would be fewer. However, the lines run close to where people live and work and under state laws, utility companies generally get right-of-ways by condemnation. There is no federal jurisdiction over power lines.

*The News Journal* Wilmington, Delaware  
November 27, 1975

### MICROWAVE COOKING OF LOW GRADE MEAT

The ABR Food Machinery Co., Ltd. and GEC-Elliott Process Automation, Ltd. have developed a process to produce meat and fish products which removes the need for casings, rendering low grade but protein rich meats palatable. The product is free from cooking loss and bacteria. The process uses MWs to cook material which has been extruded from a continuous vacuum processor. The cooked material is then cut or diced. The purpose of the system is to produce meat cubes and similar ingredients for pies, ready meals, and canned products. It can also be used for manufacturing skinless sausages. It is claimed that the product is a solid cube of meat in which tough constituents such as sinew and gristle are made palatable. The end product of the process can withstand freezing, boiling, baking and retorting temperatures without disintegration. Cooking losses are under 5% because the meat cooks almost instantaneously in metal tubes which pass between two microwave guides.

*Food Manufacture* 50(8):24, 1975

### MAGNETIC FIELDS AND HUMANS

Whether humans sense and are affected by magnetic fields is presently being studied at the University of Minnesota. Otto H. Schmitt, chairman of the Bio-Physics Group and professor of electrical engineering, began the two year study after serving on an American Institute of Biological Sciences committee that alerted the U.S. Navy to possible biological dangers from Project Sanguine. In this study, volunteers were placed in a box that screened out all external magnetic fields. Then a magnetic field was generated inside the box, and turned on and off at random. None of the 500 subjects could tell consistently when the low frequency fields used in this study were on.

*Popular Science* 207(4):22, 1975

### OPPOSITION TO PROPOSED DIATHERMY STANDARD

The Technical Electronic Product Radiation Safety Standards Committee of the BRH recently proposed a standard for MW diathermy equipment. At a public meeting held in Rockville, Maryland in September, the IEEE Committee on Man and Radiation's opposing position was presented. COMAR believes that unnecessary restrictions on the use of diathermy equipment by qualified practitioners is undesirable and that it would be better to regulate the qualifications of diathermy operators than to limit the flexibility of the equipment. The question of limits should concern only the power density impinging on portions of the body that are not to be heated and on equipment operators after appropriate screening and shielding. The proposed standard appears to be unnecessary and could seriously hamper the beneficial applications of MW radiation in biology and medicine.

*IEEE Spectrum* 12(11):20, 1975

### MICROWAVE THERMOGRAPHY FOR CANCER AND STROKE DETECTION

Alan H. Barrett and Philip C. Meyers of MIT have developed a technique capable of detecting abnormal temperatures within body tissues as deep as 10 cm. Microwave thermography uses a radiometer sensor attached to the skin to measure heat radiated by internal tissue in the form of microwaves. Abnormal temperatures often signify developing tumors of the breast or reduced blood flow indicative of the onset of a stroke.

*Chemical and Engineering News* 53(46):31, 1975

## NEWS ITEMS

*Biological Effects Electromagnetic  
Radiation 11(4), December 1975*

### ELECTRIC CURRENT TO HEAL BONES

For more than four years, surgeons at the Hospital of the University of Pennsylvania have been using low voltage electric current to help broken bones heal. They have learned where it is best to place the electrodes and the optimum voltage for various fractures. However, it is not known why it works. Both biochemical and biophysical factors are involved.

*The Evening Bulletin* November 4, 1975

### ITEMS FROM THE COMMERCE BUSINESS DAILY

- RESEARCH ON MICROWAVE RADIATION.

The Office of Naval Research, Arlington, Virginia, has contracted with Battelle Memorial Institute, Richland, Washington, for the above study. (November 4, 1975)

- DEVELOPMENT OF ED MODEL OF AN EM RADIATION SYSTEM.

The USAECOM Procurement Division, Fort Monmouth, New Jersey, has contracted with AEL Service Corporation, Colmar, Pennsylvania, for the above study. (November 5, 1975)

- FURTHER RESEARCH ON DETERMINING THE INFLUENCE OF EMBRYONIC EXPOSURE TO MICROWAVES ON POST-NATAL BEHAVIOR AND GROWTH RATE.

The Office of Naval Research, Arlington, Virginia, proposes to negotiate with the Institute for Behavioral Research, Inc., Silver Spring, Maryland, for the above study. (November 20, 1975)



## MEETINGS AND CONFERENCES

### \*\*\*\* 1975 ANNUAL MEETING OF THE USNC-URSI

Date: October 20-23, 1975

Place: Boulder, Colorado

Sponsor: URSI, IEEE

Requests for Information: Prof. J. R. Wait, Rm. 242,  
RBL, CIRES, University of Colorado, Boulder, Colorado  
80302

*Selected Bibliography of Papers to be Presented:*

MICROWAVE HEARING IN MAMMALS AT 3.0 GHz. C. A. Cain (Bioacoust. Res. Lab., Univ. Illinois, Urbana) and W. J. Rissmann.

A THEORETICAL STUDY OF MICROWAVE-GENERATED AUDITORY PHENOMENA IN MAMMALIAN CRANIAL STRUCTURES. J. C. Lin (Dep. Electr. Eng., Wayne State Univ., Detroit, Mich.) and C-K. Lam.

MICROWAVE-INDUCED AUDITORY RESPONSE--COCHLEAR MICROPHONICS. C. K. Chou (Dep. Rehabil. Med., Univ. Washington Sch. Med., Seattle), A. W. Guy, and R. Galambos.

DISCRIMINATIVE CONTROL OF APPETITIVE BEHAVIOR BY PULSED MICROWAVE RADIATION IN RATS. R. B. Johnson (Dep. Rehabil. Psychol., Univ. Washington, Seattle), D. Meyers, A. W. Guy, R. H. Lovely, and R. Galambos.

RF SOUND: POSSIBLE MECHANISMS AS DEFINED BY RECENT RESEARCH. E. S. Eichert (Randomline, Inc., Huntingdon Valley, Pa.) and A. H. Frey.

BIOLOGICAL THERMAL EFFECT OF MICROWAVE RADIATION ON HUMAN EYES. K. A. Al-Badwaih (Dep. Electr. Eng., Cairo Univ., Egypt) and A-B. Youssef.

EFFECTS OF 35 AND 107 GHz CW MICROWAVES ON THE RABBIT EYE. L. Birenbaum (Polytech. Inst. New York, Brooklyn), I. T. Kaplan, W. Metlay, S. W. Rosenthall, and M. M. Zaret.

MECHANISM OF MICROWAVE CATARACTOGENESIS IN RABBIT EYES. P. Kramar (Dep. Rehabil. Med., Univ. Washington Sch. Med., Seattle), C. Harris, A. W. Guy, and A. Emery.

THE EFFECT OF CATARACTOGENIC DOSES OF MICROWAVE RADIATION ON LENTICULAR TRANSPORT. J. R. Rabinowitz (New York Univ. Med. Cent., Inst. Environ. Med., New York).

A ROSE OF ANOTHER NAME IS A CABBAGE. D. R. Justesen (VA Hosp., Kansas City, Mo.).

STEADY STATE TEMPERATURE PROFILES IN MICROWAVE DIATHERMY. K. A. Al-Badwaih (Dep. Electr. Eng., Cairo Univ., Egypt) and A-B. A. Youssef.

PHYSIOLOGIC DESIGN CRITERIA FOR THERAPEUTIC APPLICATORS OPERATING AT 915 MHz. J. F. Lehmann (Dep. Rehabil. Med., Univ. Washington, Seattle), A. W. Guy, and J. B. Stonebridge.

MAPPING OF FREE SPACE AND SCATTERED FIELDS IN MICROWAVE DIATHERMY. G. Kantor (Div. Electron. Prod., BRH, FDA, Rockville, Md.), H. Bassen, and M. Swicord.

SHORTWAVE DIATHERMY APPLICATORS. A. W. Guy (Dep. Rehabil. Med., Univ. Washington, Seattle), J. A. McDougall, and M. D. Webb.

MICROWAVE-INDUCED HYPERTHERMIA AND RADIATION SENSITIVITY OF MOUSE INTESTINE. G. A. Gordon (Dep. Radiol., Univ. Utah, Salt Lake City), G. Livingston, and L. A. Dethlefsen.

BIOLOGIC EFFECTS OF PULSED HIGH FREQUENCY ELECTROMAGNETIC RADIATION. B. West (Med. Coll. Virginia, Richmond) and W. Regelson.

MICROWAVE RADIATION AS A DIAGNOSTIC TOOL. P. C. Pedersen (Univ. Utah, Salt Lake City), C. C. Johnson, C. H. Durney, and D. G. Bragg.

REMOTE MEASUREMENT OF RESPIRATION IN INFANT PRIMATES USING AN X-BAND DOPPLER RADAR. F. A. Spelman (Reg. Primate Res. Cent., Univ. Washington, Seattle), C. W. Kindt, D. M. Bowden, G. P. Sackett, J. E. Spillane, and D. A. Blattman.

ANTENNA DESIGN FOR A PASSIVE TEMPERATURE MONITORING AND IDENTIFICATION SYSTEM FOR LIVESTOCK. J. A. Landt (Los Alamos Sci. Lab., N.M.).

E- AND H-FIELD INSTRUMENTATION AND CALIBRATION BELOW 500 MHz. P. S. Ruggera (Div. Electron. Prod., BRH, FDA, Rockville, Md.).

MAGNETIC FIELD STANDARD AT FREQUENCIES ABOVE 30 MHz. H. Trzaska (Tech. Univ. Wroclaw, Poland).

A LOW FREQUENCY H-FIELD RADIATION MONITOR. E. Aslan (Narda Microwave, Plainview, N.Y.).

COMPLETE MEASUREMENT OF HAZARDOUS ELECTROMAGNETIC FIELDS WITH ELECTRO OPTICAL CRYSTALS. H. Bassen (BRH, FDA, PHS, Rockville, Md.) and R. Peterson.

MEASUREMENT OF ELECTRIC AND MAGNETIC FIELD STRENGTHS FROM INDUSTRIAL RADIOFREQUENCY (10-40 MHz) POWER SOURCES. D. L. Conover (NIOSH, DLCD, PAB, Cincinnati, Ohio), W. H. Parr, E. L. Sensintaffar, and W. E. Murray, Jr.

METHODS AND INSTRUMENTATION FOR THE EVALUATION AND CALIBRATION OF MICROWAVE SURVEY INSTRUMENTS. M. L. Swicord (Div. Electron. Prod., BRH, FDA, Rockville, Md.), H. I. Bassen, W. A. Herman, J. E. Duff, and J. R. Bing.

MUTUAL COUPLING BETWEEN LINEAR ANTENNAS. M. L. Swicord (Div. Electron. Prod., BRH, FDA, Rockville, Md.) and A. Y. Cheung.

RESPIRATORY ACTIVITY OF MITOCHONDRIA EXPOSED IN A COAXIAL AIRLINE TO 2000-4000 MHz MICROWAVE RADIATION. J. A. Elder (Exp. Biol. Div., EPA,



## MEETINGS AND CONFERENCES

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Research Triangle Park, N.C.), J. S. Ali, and M. D. Long.

THE EFFECT OF MICROWAVES (2450 MHz) ON LYMPHOCYTE BLAST TRANSFORMATION IN VITRO. R. J. Smialowicz (Exp. Biol. Div., EPA, Research Triangle Park, N. C.).

MICROWAVE PERTURBATION ON CELLULAR ENZYMATIC REACTIONS. S. T. Hsieh (Tulane Univ., New Orleans, La.) and Y. J. Seto.

A SUMMARY OF CELL AND TISSUE LEVEL EVENTS PRODUCED BY RF FIELDS PREDICTED FROM CONSIDERATION OF REGIONAL HYPERTHERMIA. J. W. Frazer (U.S. Air Force Sch. Aerosp. Med., Brooks Air Force Base, Tex.).

EFFECTS OF MICROWAVE RADIATION ON MAMMALIAN CELLS IN VITRO. J. C. Lin (Dep. Electr. Eng., Wayne State Univ., Detroit, Mich.) and K. C. Chen.

EVALUATION OF DOMINANT LETHAL TEST AND DNA STUDIES IN MEASURING MUTAGENICITY CAUSED BY NON-IONIZING RADIATION. M. M. Varma (Dep. Bio-Environ. Eng., Sch. Eng., Howard Univ., Washington, D.C.) and E. A. Trabculay.

MUTAGENICITY INDUCED BY NON-IONIZING RADIATION IN SWISS MALE MICE. M. M. Varma (Bio-Environ. Eng., Sch. Eng., Howard Univ., Washington, D.C.), E. L. Dage, and R. Joshi.

THE EFFECT OF MICROWAVE EXPOSURE ON BACTERIA: MUTATION INDUCTION. C. F. Blackman (Exp. Biol. Div., EPA, Research Triangle Park, N. C.), M. C. Surles, and S. G. Benane.

DEPENDENCE OF TOTAL AND DISTRIBUTED ABSORBED MICROWAVE ENERGY UPON SIZE, SHAPE, AND ORIENTATION OF RAT PHANTOMS IN WAVEGUIDE. A. Leicher-Preka (Inst. Physiol Biochem. Med. Fac., Sarajevo, Yugoslavia) and H. S. Ho.

CONSIDERATIONS OF CHAMBER DESIGN, ENVIRONMENTAL CONTROL, AND MICROWAVE FIELD INTERACTIONS IN SMALL ANIMAL EXPERIMENTATION. W. M. Houk (Naval Aerosp. Med. Res. Lab., Pensacola, Fla.), J. D. Grissett, and A. Longacre, Jr.

CHRONIC EXPOSURE OF A RAT POPULATION BY CIRCULARLY POLARIZED GUIDED WAVES. A. W. Guy (Dep. Rehabil. Med., Univ. Washington Sch. Med., Seattle), C. K. Chou, and R. H. Lovely.

MICROWAVE IRRADIATION APPARATUS DESIGN AND DOSIMETRY. H. S. Ho (BRH, Rockville, Md.), M. R. Foster, and M. L. Swicord.

ADRENOCORTICAL RESPONSE IN RATS EXPOSED TO MICROWAVES. W. G. Lotz (Univ. Rochester, N.Y.) and S. M. Michaelson.

A UNIQUE ELECTROMAGNETIC ENVIRONMENTAL SIMULATOR. E. R. Graf (Electr. Eng. Dep., Auburn Univ., Ala.), D. G. Burks, and F. E. Cole.

FIELD MEASUREMENTS FOR A SERIES OF BEHAVIORAL STUDIES. V. R. Reno (Naval Aerosp. Med. Res. Lab., Pensacola, Fla.) and J. O. deLorge.

STUDY OF THE MICROWAVE-INDUCED PERTURBATIONS OF THE BEHAVIOUR BY THE OPEN-FIELD TEST INTO THE WHITE RAT. J. Gillard (Hosp. Instr. Armees Sainte-Anne, 83800 Toulon Naval, France), B. Servantie, G. Bertharion, A. M. Servantie, J. Obrenovitch, and J. C. Perrin.

"AVOIDANCE" BY RATS OF A 2.88 GHz PULSE MICRO-WAVE FIELD. E. L. Hunt (Walter Reed Army Inst. Res., Washington, D.C.), N. W. King, and R. H. Lovely.

ALTERATIONS IN THE SLEEP PROCESS OF THE RABBIT AS A FUNCTION OF CHRONIC LOW INTENSITY ELECTROMAGNETIC RADIATION EXPOSURE. R. C. Manthei (Biomed. Res. Lab., Naval Surf. Weapons Cent., Dahlgren, Va.) and Z. R. Glaser.

THE EFFECTS OF 1.7 AND 2.45 GHz MICROWAVES ON DRUG-INDUCED SLEEPING TIME IN THE RABBIT. Cleary, S. F. (Dep. Biophys., Virginia Commonw. Univ., Richmond.).

MODIFICATION OF INTERNAL DISCRIMINATIVE STIMULUS CONTROL OF BEHAVIOR BY LOW LEVELS OF PULSED MICROWAVE RADIATION. J. R. Thomas (Naval Med. Res. Inst., Bethesda, Md.), S. S. Yeandle, and L. S. Burch.

BEHAVIORAL EFFECTS OF RESONANT ELECTROMAGNETIC POWER ABSORPTION IN RATS. J. A. D'Andrea (Dep. Electr. Eng. Bioeng., Univ. Utah, Salt Lake City), O. P. Gandhi, and R. P. Kesner.

THE EFFECTS OF MICROWAVE RADIATION ON BEHAVIOR AND TEMPERATURE IN RHESUS MONKEYS. J. O. deLorge (Naval Aerosp. Med. Res. Lab., Pensacola, Fla.).

MICROWAVE AND INFRARED RADIATION EFFECTS ON AN OPERANT RESPONSE IN RHESUS MONKEYS. R. D. McAfee (VA Hosp., New Orleans, La.), S. T. Elder, T. J. Lipscomb, J. G. May, and M. G. Holland.

A TWO IMPEDANCE METHOD FOR WIDE RANGE DIELECTROMETRY. M. Swicord (Div. Electron. Prod., BRH, FDA, Rockville, Md.), J. Saffer, and A. Cheung.

WIDE-BAND CHARACTERIZATION OF DIELECTRIC AND HEAT PROPERTIES OF SIMULATED BIOTISSUES. A. Y. Cheung (Inst. Fluid Dyn. Appl. Math., Univ. Maryland, College Park), D. W. Koopman, and M. L. Swicord.

THE ATTENUATION FUNCTION FOR BIOLOGICAL FLUIDS OF MILLIMETER AND FAR-INFRARED WAVELENGTHS. K. H. Illinger (Dep. Chem., Tufts Univ., Medford, Mass.).

ELECTRIC DIPOLE INTERACTIONS FOR MICROWAVE PULSES AND DAMAGE TO EMBRYOS. S. D. Pyle (Dep. Electr. Eng., Univ. Colorado, Boulder), C. L. Hu, R. Caldwell, and F. S. Barnes.

MICROWAVE-INDUCED AVOIDANCE BEHAVIOR IN THE MOUSE. J. C. Monahan (BRH, Rockville, Md.) and H. S. Ho.

PHYSIOLOGICAL AND BEHAVIORAL EFFECTS OF CHRONIC LOW LEVEL MICROWAVE RADIATION OF RATS. K. E. Moe (Dep. Rehabil. Med., Univ. Washington, Seattle), R. H. Lovely, and A. W. Guy.

THEORETICAL CALCULATIONS OF POWER ABSORBED BY MONKEY AND HUMAN SPHEROIDAL AND ELLIPSOIDAL PHANTOMS IN AN IRRADIATION CHAMBER. H. Massoudi (Univ. Utah, Salt Lake City), C. H. Durney, C. C. Johnson, and S. Allen.

MEASUREMENT OF RADIOFREQUENCY POWER ABSORPTION IN MONKEYS, MONKEY PHANTOMS, AND HUMAN PHANTOMS EXPOSED TO 10-50 MHz FIELDS. S. J. Allen (U.S. Air Force Sch. Aerosp. Med., Radiobiol. Div., Brooks Air Force Base, Tex.), W. D. Hurt, J. H. Krupp, J. A. Ratliff, C. J. Durney, and C. C. Johnson.

POWER DEPOSITION IN A MULTILAYERED SPHERICAL MODEL OF THE HUMAN HEAD. S. M. Neuder (Div. Electron. Prod., BRH, FDA, Rockville, Md.), D. H. Hill, and R. B. Kellogg.

DISTRIBUTION OF ELECTROMAGNETIC ENERGY DEPOSITION IN MODELS OF MAN WITH FREQUENCIES NEAR RESONANCE. O. P. Gandhi (Dep. Electr. Eng. Bioeng., Univ. Utah, Salt Lake City), K. Sedigh, G. S. Beck, and E. L. Hunt.

MODELS OF BIOLOGIC INTERACTION WITH ELECTROMAGNETIC FIELDS. J. MacDougal (Dep. Rehabil. Med., Univ. Washington, Seattle), M. Webb, and J. W. Frazer.

MICROWAVE-INDUCED SHIFTS OF GONADOTROPIC ACTIVITY IN ANTERIOR PITUITARY GLAND OF RATS. H. Mikolajczyk (Inst. Occup. Med., 90-950 Lodz, Poland).

THE EFFECT OF 1.6 GHz CW FIELDS ON TRACE METAL CONTENT OF SPECIFIC REGIONS OF RAT BRAIN. F. Chamness (U.S. Air Force Sch. Aerosp. Med., Brooks Air Force Base, Tex.), H. Scholes, S. Sexauer, and J. W. Frazer.

INTERACTION OF MODULATED ELECTROMAGNETIC FIELDS WITH NERVOUS STRUCTURES. C-L. Wu (Dep. Electr. Eng., Wayne State Univ., Detroit, Mich.) and J. C. Lin.

THE EFFECT OF 1.6 GHz RADIATION ON NEUROTRANSMITTERS IN DISCRETE AREAS OF THE RAT BRAIN. J. H. Merritt (Radiobiol. Div., U.S. Air Force Sch. Aerosp. Med., Brooks Air Force Base, Tex.), R. Hartzell, and J. H. Frazer.

NUMERICAL STUDY OF ELECTROMAGNETIC POWER DEPOSITION IN BIOLOGICAL TISSUE BODIES. P. W. Barber (Univ. Utah, Salt Lake City).

FINITE ELEMENT-VARIATIONAL CALCULUS APPROACH TO THE DETERMINATION OF ELECTROMAGNETIC FIELDS IN IRREGULAR GEOMETRY. S. M. Neuder (Div. Electr. Prod., BRH, FDA, Rockville, Md.) and P. H. E. Meijer.

ELECTROMAGNETIC RADIATION EFFECTS ON THE BLOOD-BRAIN BARRIER SYSTEM OF RATS. K. J. Oscar (U.S. Army Mobility Equip. Res. Dev. Cent., Fort Belvoir, Va.) and T. D. Hawkins.

REDUCTION IN SENSITIVITY TO AUDIOGENIC SEIZURE FOLLOWING A SINGLE, 2450 MHz, CW IRRADIATION OF RATS. T. D. Hawkins (Dep. Microwave Res., Walter Reed Army Inst.-Res., Washington, D.C.) and E. L. Hunt.

NONTHERMAL EFFECTS OF ELECTROMAGNETIC FIELDS ON THE CENTRAL NERVOUS SYSTEM. H. Kritikos (Dep. Bioeng., Univ. Pennsylvania, Philadelphia) and S. Takashima.

LIGHT AND ELECTRON MICROSCOPIC INVESTIGATION OF BRAINS EXPOSED TO NON-IONIZING RADIATION. E. N. Albert (Dep. Anat., George Washington Univ. Med. Cent., Washington, D.C.).

ELECTROMAGNETIC POWER ABSORPTION IN LOSSY WIRE MODEL OF MAN. K. R. Umashankar (Dep. Electr. Eng., Univ. Mississippi, University) and C. M. Butler.

NUMERICAL SIMULATION OF THE EFFECTS OF NONIONIZING R.F. RADIATION UPON THE HUMAN BODY. A. F. Emery (Dep. Mech. Eng., Univ. Washington, Seattle), A. W. Guy, K. K. Kraning, and R. Short.

COLONIC TEMPERATURE CHANGES DURING MICROWAVE EXPOSURE. S. H. Githens (Dep. Microwave Res., Walter Reed Army Inst. Res., Washington, D.C.), T. D. Hawkins, and J. Schrot.

MICROWAVE FREQUENCY AND E-FIELD ORIENTATION INTERACT WITH ANIMAL SIZE. J. Schrot (Dep. Microwave Res., Walter Reed Army Inst. Res., Washington, D.C.) and T. D. Hawkins.

EFFECTS OF WEAK LOW FREQUENCY ELECTRIC FIELDS ON CALCIUM EFFLUX FROM ISOLATED CHICK AND CAT BRAIN. S. M. Bawin (Dep. Anat. Physiol., Brain Res. Inst., Univ. California, Los Angeles) and W. R. Adey.

LONG-TERM EFFECTS OF WEAK 45-75 Hz ELECTROMAGNETIC FIELDS ON THE SLIME MOLD PHYSARUM POLYCEPHALUM. B. Greenebaum (Div. Sci., Univ. Wisconsin-Parkside, Kenosha), E. M. Goodman, and M. T. Marron.

EFFECTS OF THE FIELD FREE SPACE ON THE CIRCADIAN ACTIVITY RHYTHM OF THE HOUSE SPARROW, PASSER DOMESTICUS, AND OF THE SONG SPARROW, MELOSPIZA MELODIA. V. Bliss (Dep. Zool., Univ. Rhode Island, Kingston) and F. Heppner.

EFFECTS OF 45 Hz ELECTRIC FIELD EXPOSURE ON RATS. N. S. Mathewson (Armed Forces Radiobiol. Res. Inst., Def. Nucl. Agency, Bethesda, Md.), G. M. Oosta, S. A. Oliva, and A. P. Blasco.

EXPOSURE OF DOMESTIC FOWL TO ELF ELECTRIC AND MAGNETIC FIELDS. W. K. Durfee (Dep. Anim. Sci., Univ. Rhode Island, Kingston), P. R. Plante, P. Marton, S. Muthukrishnan, and C. Polk.

## MEETINGS AND CONFERENCES

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HIGH VOLTAGE ELECTRIC FIELD COUPLING TO HUMANS USING MOMENT METHOD TECHNIQUES. R. J. Spiegel (IIT Res. Inst., Washington, D.C.).

THE EFFECTS OF WEAK ELF ELECTRIC FIELDS ON SCHEDULE-CONTROLLED BEHAVIOR OF MONKEYS. R. G. Medici (Brain Res. Inst., Univ. California, Los Angeles).

EFFECT OF AC ELECTRIC FIELD APPLICATION UPON HUMAN VISUAL THRESHOLD. S. Sugiyama (Kwansei Gakuin Univ., Nishinomiya, Hyogo, Japan) and K. Mizuno.

IMPACT OF EXTREMELY LOW FREQUENCY ELECTROMAGNETIC FIELDS ON ANIMALS IN NATURE. B. Greenberg (Prof. Biol. Sci., Univ. Illinois Chicago Circle, Chicago).

PHYSIOLOGICAL BASIS OF HUMAN ELECTRIC SHOCK THRESHOLD. W. P. Moran (Dep. Phys., Univ. Tulsa, Oklahoma).

USE OF DIELECTRIC MICROPROBES FOR ELECTROMAGNETIC FIELD MEASUREMENT. A. Deficis (Microwave Dep., O.N.E.R.A.-C.E.R.T., 31055 Toulouse Cedex, France).

PERFORMANCE OF THE LCOF PROBE IN CALORIMETRIC AND TISSUE TEMPERATURE MONITORING APPLICATIONS. G. K. Livingston (Univ. Utah, Salt Lake City), C. C. Johnson, C. H. Durney, and T. C. Rozzell.

A BIREFRINGENT CRYSTAL OPTICAL THERMOMETER FOR MEASUREMENTS OF ELECTROMAGNETICALLY INDUCED HEATING. T. C. Cetas (Div. Electron. Prod., BRH, FDA, Rockville, Md.).

OPTICAL ETALON TEMPERATURE SENSOR FOR MICROWAVE TISSUE HEATING APPLICATIONS. D. A. Christensen (Dep. Electr. Eng. Bioeng., Univ. Utah, Salt Lake City).

A TEMPERATURE PROBE FOR RF HEATED MATERIAL. R. R. Bowman (Nat'l. Bur. Stand., Boulder, Colo.).

QUANTIFICATION AND MEASUREMENT OF INDUCED FIELDS INSIDE FINITE BIOLOGICAL BODIES. K. M. Chen (Dep. Electr. Eng. Syst. Sci., Michigan State Univ., East Lansing), B. S. Guru, and D. P. Nyquist.

EXPERIMENTAL CALIBRATION OF A MINIATURE ELECTRIC FIELD PROBE WITHIN MUSCULAR TISSUES. A. Y. Cheung (Inst. Fluid Dyn. Appl. Math., Univ. Maryland, College Park), M. L. Swicord, and H. I. Bassen.

THE EFFECTS OF ENVIRONMENTAL TEMPERATURE ON THERMOREGULATORY, SERUM LIPID, CARBOHYDRATE, AND GROWTH HORMONE RESPONSES OF RATS EXPOSED TO MICROWAVE. W. M. Houk (Naval Aerosp. Med. Res. Lab., Pensacola, Fla.), S. M. Michaelson, and D. E. Beischer.

THE EFFECTS OF 19 MEGACYCLE IRRADIATION ON MICE

AND RATS. W. B. Stavinocha (Univ. Texas Health Sci. Cent., San Antonio), M. A. Medina, S. T. Weintraub, D. H. Ross, and A. T. Modak.

LONG TERM EXPOSURE STUDIES OF HIGH PEAK POWER (HPP) PULSED ELECTROMAGNETIC RADIATION ON MICE. T. C. O'Grady (Biomed. Res. Lab., Naval Surf. Weapons Cent., Dahlgren, Va.) and Z. R. Glaser.

INVESTIGATION OF ELECTROMAGNETIC EFFECTS OF A 1000-FOOT TV TOWER ON MIGRATORY BIRDS. D. G. Burks (Electr. Eng. Dep., Auburn Univ., Ala.) and E. R. Graf.

SOME DEVELOPMENTAL AND BEHAVIORAL FACTORS OF LOW INTENSITY X-BAND RADIATION. C. W. Kindt (Reg. Primate Cent. Univ. Washington, Seattle), D. M. Bowden, F. A. Spelman, and M. K. Morgan.

THE BIOLOGICAL SIGNIFICANCE OF RADIOFREQUENCY RADIATION EMISSION CHARACTERISTICS ON CARDIAC PACEMAKER PERFORMANCE. J. C. Mitchell (U.S. Air Force Sch. Aerosp. Med., Radiobiol. Div., Brooks Air Force Base, San Antonio, Tex.) and W. D. Hurt.

BROADCAST RADIATION: A SECOND LOOK. R. A. Tell (EPA, Washington, D.C.) and D. E. Jones.

HEALTH HAZARDS IN MICROWAVE FIELDS. K. D. Woolas (MOD, United Kingdom).

CRITICAL ASPECTS OF HUMAN VERSUS TERRESTRIAL ELECTROMAGNETIC SYMBIOSIS. E. S. Maxey (Res. Div., Miami Heart Inst., Fla.).

THE INFLUENCE OF MICROWAVE EXPOSURE ON NEUROENDOCRINE FUNCTION IN THE RAT AND DOG. S. M. Michaelson (Univ. Rochester, N.Y.).

PSEUDOSUBSTRATE BINDING TO RIBONUCLEASE DURING EXPOSURE TO MICROWAVE RADIATION AT 1.70 AND 2.45 GHz. J. W. Allis (Exp. Biol. Div., EPA, Research Triangle Park, N.C.) and M. L. Fromme.

CHRONIC LOW-LEVEL EXPOSURE OF RABBITS TO MICROWAVES. E. S. Ferri (Div. Biol. Eff., BRH, FDA, HEW, Winchester, Mass.) and G. J. Hagan.

MICROWAVE FREQUENCY AS A FACTOR IN THE INDUCTION OF LENS OPACITIES IN THE RABBIT EYE. G. J. Hagan (Div. Biol. Eff., BRH, FDA, HEW, Winchester, Mass.) and R. L. Carpenter.

A STUDY OF THE EFFECTS OF MICROWAVE IRRADIATION OF THE RAT TESTES. G. J. Muraca, Jr. (Div. Biol. Eff., BRH, FDA, HEW, Winchester, Mass.) and E. S. Ferri.

COMPARISON OF THERMAL EFFECTS IN THE RABBIT EYE FROM MICROWAVE RADIATION AND FROM EXTERNAL HEATING. R. L. Carpenter (Div. Biol. Eff., BRH, FDA, HEW, Winchester, Mass.) and G. J. Hagan.

THE USE OF STRIPLINE TO STUDY MICROWAVE BIOLOGICAL EFFECTS. R. L. Seaman (Dep. Biomed. Eng., Duke Univ., Durham, N.C.), H. Wachtel, and W. T. Joines.



BIOMEDICAL ASPECTS OF RADIOFREQUENCY AND MICROWAVE RADIATION: A REVIEW OF SELECTED SOVIET, EAST EUROPEAN, AND WESTERN REFERENCES. Z. R. Glaser (Biomed. Res. Detachment, Naval Surf. Weapons Cent., Dahlgren, Va.) and C. H. Dodge.

THEORETICAL CALCULATIONS OF POWER ABSORBED BY AN ELLIPSOIDAL MODEL OF MAN AND ANIMALS IN AN ELECTROMAGNETIC PLANE WAVE. H. Massoudi (Univ. Utah, Salt Lake City), C. H. Durney, C. C. Johnson, and S. Allen.

TIME-COURSE OF ADRENAL RESPONSE IN MICROWAVE-EXPOSED RATS. R. Guillet (Univ. Rochester, N.Y.), W. G. Lotz, and S. M. Michaelson.

THYROID RESPONSE TO LOCALIZED MICROWAVE EXPOSURE. R. L. Magin (Univ. Rochester, N.Y.), S-T. Lu, and S. M. Michaelson.

ELECTROMAGNETIC FIELD EFFECTS ON ISOLATED NERVE TISSUE. S. S. Sandler (Bioelectromagn. Lab., Dep. Electr. Eng. Northeastern Univ., Boston, Mass.).

\*\*\*\* CONFERENCE ON ENGINEERING IN MEDICINE AND BIOLOGY

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*Selected Bibliography of Papers to be Presented:*

DIAGNOSTIC APPLICATION OF MICROWAVE RADIATION.

P. C. Pedersen (Univ. Utah, Salt Lake City), C. C. Johnson, D. H. Durney, and D. G. Bragg.



## CURRENT LITERATURE

- 0621 THE EFFECT OF RADAR ON CARDIAC PACEMAKERS.  
(E.) Rohl, D. (Dep. Cardiol., Univ. Ulm, Germany), H. M. Laun, M. E. T. Hauber, M. Stauch, and H. Voigt. *ISA Trans.* 14(2):115-117, 1975.

Noncompetitive cardiac pacemakers may detect electrical signals from outside the body which can modify their behavior. The interference susceptibility of 16 of these pacemakers to radiation from the most powerful civil radar system in Europe was investigated in the laboratory and 1.2 km from the radar station. The system operates with a RF output power of  $5 \times 10^6$  W, 1.3 GHz frequency and a duty cycle of 0.002. Tests were performed in the laboratory in air, fat, water, 0.9% NaCl, and after implantation in dogs and humans. The layer of fat or solution was kept constant at 1 cm in front of the pacemaker, and the electrode length was  $\lambda/4$  so that it constituted an optimal receiving antenna. By varying pacemaker orientation, electrode length, and electrode position independently, it was shown that the susceptibility of the pacemakers was determined by radiation received through the electrode acting as an antenna in air. Laboratory tests indicated that fat provided the least shielding, similar to that of air. The testing therefore took place in air with an electrode length of  $0.25\lambda$  and pacemaker and electrode in their most sensitive orientations. Two conclusions were drawn: (1) metal encapsulation of the pulse generator did not provide sufficient shielding because it did not prevent the entry of radiation along the electrode, and none of the pacemakers remained undisturbed at the biological tolerance limit of  $10 \text{ mW/cm}^2$ . To protect pacemakers optimally, several units were modified by metal encapsulation of the pulse generator and a low-pass filter at the electrode. With these alterations, they were undisturbed at pulse power densities far above  $10 \text{ W/cm}^2$ . (5 references)

- 0622 GONADIC FUNCTION IN WORKMEN WITH LONG-TERM EXPOSURE TO MICROWAVES. (E.) Lancranjan, I. (Dep. Occup. Dis., Inst. Hyg. Public Health, Bucharest, Romania), M. Maicanescu, E. Rafaila, I. Klepsch, and H. I. Popescu. *Health Phys.* 29(3):381-383, 1975.

Thirty-one technicians (mean age 33 yr) with an average exposure of 8 yr to MWs with frequencies between 10,000 and 3600 MHz were investigated for gonadic function. The complex clinical examination included endocrinologic and andrologic examinations to eliminate those with endocrinologic diseases, venereal diseases, varicocele, hydrocele, testicular trauma, and other causes which could influence spermatogenesis. Spermatic liquid analyses were carried out after at least 3 days of sexual rest. Volume, motility, spermatozoa/ml and percentage of abnormal spermatozoa were measured. The elimination of total neutral 17 ketosteroids and total gonadotropins in 24 hr urine were determined in 19 technicians. Results were compared to controls without occupational exposure to chemical noxae or ionizing radiation. Seventy percent of the technicians showed decreases in libido and disturbances in erection, ejaculation, and/or orgasm. Alterations in spermatogenesis were present in 74% of the technicians. Results of 17 ketosteroids

and total gonadotropins were essentially normal, ruling out the possibility that spermatogenesis alterations were secondary to central diencephalopituitary disorder. The alterations seen in technicians exposed for a long term to relatively high intensity MWs were probably due to MW exposure as two-thirds of the technicians reinvestigated 3 mon after interruption of exposure showed improvement in spermatogenesis. (6 references)

- 0623 HEALTH HAZARDS FROM MICROWAVE EXPOSURE.  
(E.) Bush, D. (Univ. Radiat. Prot. Off., Univ. Birmingham, England). *Health Phys.* 29(3):431, 1975.

It is again noted that there is little research coordination into the basic understanding of the problems presented by MWs, including the nature and scale of biological effects. There is little international cooperation, discussion, and agreement on standards, as exemplified by the 1000-fold difference of maximum permissible exposure levels between the USSR and the USA and UK. The case of long term low level effects vs acute thermal effects should be explored and resolved. (4 references)

- 0624 LASER RADIATION AND MICROWAVES; THEIR IMPAIRMENT OF THE HUMAN BODY AND THE MEASURES FOR PROTECTION. (Jap.) Iida, H. (Natl. Inst. Radiol. Sci., Jap.). *Saf. Dig. (Jap.)* 21(4):166-176, 1975.

The impairment of laser and MW radiation on the human body is reviewed. The MW radiation causes both thermal and nonthermal effects, and the latter effect is an obstruction in the nervous system and cell metabolism. The thermal effect depends on the energy absorptivity, specific gravity, and specific heat of the individual tissue or organ, and also depends on how the accumulated heat can be transported to the neighboring tissues or environments. Therefore, the MW radiation causes less obstruction on the human skin than the tissues inside the human body; however, the thermal effect on crystalline lens and testicles is large because of the lack of blood circulation for heat transfer. Cataracts may be caused by a large amount of MW irradiation. The US Air Force employs the value of  $0.01 \text{ W/cm}^2$  as the maximum allowed MW energy for eye safety. A 50% increase in the leukocytes is reported in experiments on rats and rabbits as the radiation effect on the erythropoietic organs. There is disagreement about the radiation effect on the CNS between scientists from the USA and USSR. The maximum allowed level for MW radiation safety also differs by countries. (10 references)

- 0625 THE EFFECTS OF MICROWAVE IRRADIATION ON INSECTS, NEMATODES, FUNGI, AND BACTERIA IN WITHERED PINE TREES. (Jap.) Yamane, A. (Natl. For. Exp. Stn., Minist. Agric. For., Tokyo, Japan), T. Kobayashi, O. Mamiya, H. Tamiya, K. Sasaki, and S. Yoshida. *Proc., 86th Annu. Meet. Jap. Dendrological Soc.*, p. 317-318, Aug. 1975.

## CURRENT LITERATURE

Biological Effects Electromagnetic  
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The lethal effects of MW irradiation on insects, nematodes, fungi, and bacteria in withered pine trees were studied using 2450 MHz MWs with output powers at 0.6 and 5.9 kW. When the speckled-longicorns of larva, prepupa, and pupa were placed in a plastic capsule and irradiated with 0.6 kW MWs, 25% of the larva longicorns died after 30 sec irradiation, and 90% of the larva longicorns died after 60 sec irradiation. The larva longicorns were more sensitive to the microwave lethal effect than the pupa longicorns. The temperatures attained at the core and under-bark of pine trees after the microwave irradiation were different, and the core temperature was higher than the under-bark temperature. This reflected the observed lethal effect, and longer irradiation time was required for killing the insects, nematodes, fungi, and bacteria which lived in the under-bark than in the core of the pine trees. The effective irradiation time was 45 sec for larve insects, 2 min for nematodes, and more than 5 min for fungi and bacteria. (1 reference)

- 0626 DISINFESTING PROCESS HERTZ ONLY INSECTS.  
(E.) Lowe, J. F. (Eur. Ed., *Design News*,  
06190-Roquebrune-Cap Martin, France). *Des. News*  
30(17):62-63, 1975.

A method has been developed to kill 100% of the living insects, grubs, eggs, and larvae in wheat by applying MW energy. The ability of the grain to germinate was unchanged. The process also prevented mold growth. Ionizing, IR, visible, UV and US radiation have all proved unsuccessful and/or uneconomical to use. The MW process involves heating the grain in a HF alternating field between a pair of capacitor plates to 63 C followed by rapid cooling to 45 C. Heating takes place simultaneously at all points within the material and is almost instantaneous. Steps in the process include pre-cleaning and prewarming, MW exposure, cooling, and transfer to storage. Heat extracted during cooling is used for prewarming. This process should be suitable for flour, oats, corn, and packaged products. It is economical and environmentally acceptable as there are no chemical or radioactive residues. (No references)

- 0627 HISTOCHEMICAL AND ULTRASTRUCTURAL ANALYSIS  
OF THE EFFECT OF ELECTROMAGNETIC RADIATION  
ON RAT LIVER AND BRAIN. (E.) Robinson, N. (Dep.  
Anat., London Hosp. Med. Sch., United Kingdom), J.  
G. Nievel and J. Anderson. *Biochem. Soc. Trans.*  
2(6):1359-1360, 1975.

Ultrastructural and histochemical effects of pulsed EMR on rat liver and brain were studied. White female Wistar rats (100 g) were exposed for 10 min to 27 MHz radiation at 300 and 500 pulses/min and duty cycles of 2.4 and 4%. The animals were sacrificed and liver and brain were rapidly excised. Light and electron microscopic studies were performed and the activities of various enzymes were determined. No significant microscopic changes were observed at either 300 or 500 pulses/min. No enzyme

changes were seen in the brain. The activities of alkaline phosphatase, 5'-nucleotidase, isocitrate dehydrogenase,  $\alpha$ -glycerophosphate dehydrogenase, lactate dehydrogenase, NADH-diaphorase, and monoamine oxidase did not change in the liver. However, rats irradiated at 500 pulses/min had decreased glucose-6-phosphate dehydrogenase and succinate dehydrogenase activities around the central veins of the liver; ATPase activity was lower around the bile canaliculi; and acid phosphatase was more diffuse in the cytoplasm of the exposed liver than in control. (1 reference)

- 0628 LONG TERM EFFECTS OF ELECTROMAGNETIC  
FIELDS ON *Physarum polycephalum*. (E.)  
Goodman, E. M. (Sci. Div., Univ. Wisconsin-Parkside,  
Kenosha), M. Marron and B. Greenebaum. *J. Cell*  
*Biol.* 63(2):117a, 1974.

The long term effects of ELF EMFs on the growth and development of *Physarum polycephalum* were studied. Cultures were continuously exposed to 75 or 60 Hz fields (2.0 G, 0.7 V/m) for up to 701 days. After 90-120 days a delay of 1-2 hr between successive mitoses in the cultures was noted. Cultures returned to control levels about 60 days after removal from the field. The ability to complete the sexual and asexual life cycles was not affected; however, subtle changes in gross morphology and a general slowdown of protoplasmic streaming were noted. (No references)

- 0629 THE INCREASED EFFECTIVENESS OF CANCER  
CHEMOTHERAPEUTIC AGENTS WHEN COMBINED  
WITH SIMULTANEOUS MICROWAVE IRRADIATION. (E.)  
Brent, R. L. (Jefferson Med. Coll., Philadelphia,  
Pa. 19107) and D. Hami. *Pediatr. Res.* 9(4):386, 1975.

A study was made of the ability to alter the effectiveness of drugs present in hyperthermic tissue when exposed to MW radiation. Methotrexate and 5-fluorouracil were administered to pregnant rats at LD/10 to LD/30 doses, and the rats were immediately exposed to MW radiation for 30 min with embryo tissues maintained at 42-43 C. The LD/50 dose of these drugs was significantly lowered in the hyperthermic embryos, indicating that MW radiation may be of use in increasing the effectiveness of the drug in the irradiated tissue. It could be utilized in situations in which a local increase in drug effectiveness may benefit the organism. (No references)

- 0630 COMPUTATION OF THE ELECTROMAGNETIC FIELDS  
AND INDUCED TEMPERATURES WITHIN A MODEL OF  
THE MICROWAVE-IRRADIATED HUMAN EYE. (E.) Taflove,  
A. (Dep. Electr. Eng., Technol. Inst., Northwestern  
Univ., Evanston, Ill.) and M. E. Brodwin. *IEEE Trans.*  
*Microwave Theory Tech.* MTT-23(11):888-896, 1975.

The use of experimental animals to establish a human



safety standard for MW radiation implies that the anatomy, physiology and electromagnetic environment of the animal can be related to that of humans. However, the role of tissue structure in determining MW absorption is possibly significant and heating potential contours may develop in different locations and at different magnitudes in man because of dimensional and structural differences in tissue anatomy. The absorbed power distribution pattern within a detailed model of the MW irradiated human eye with its bony orbit has been computed at 750 MHz and 1.5 GHz frequencies of planewave irradiation, and temperature distribution within the eye has been calculated. The fields are computed using a finite difference, time-domain solution of Maxwell's equations. A numerical solution of the heat conduction equation for the eyeball is also given, using the computed MW heating function as the source function. The heating potential due to irradiation at 750 MHz peaks at the muscle interface at the front of the eye and decreases with depth. At 1.5 GHz irradiation, a pronounced peak is found near the center of the eyeball and the potential also peaks strongly at the muscle interfaces below and in front of the eye. The frequency dependent position of the heating potential peak can be explained on the basis of distinct resonances of the eye scatterer and head as a whole. At lower frequency, the dimensions of the eye orbit are too small to support a wave concentration effect, but at higher frequencies a resonant behavior independent of possible concentration effects of the whole head can be supported. The heat conduction model developed has as its basic assumption that the chief cooling mechanism of the eye is the retinal blood supply localized at the surface of the eyeball. At 750 MHz irradiation, the peak temperature of 40.4 C is located at about the center of the eyeball. The lens temperature is much higher at 1.5 GHz because the surface cooling mechanism is less effective than for the shallow 750 MHz heating pattern. This is a strong indication that tissue thermodynamics must be considered when analyzing MW heating of organs. Comparison of these results with those obtained by Guy *et al.* for the rabbit eye indicates the possibility of relating MW heating patterns within the respective organs. A more detailed human model and computer runs for higher frequencies are needed. (25 references)

0631 BIOLOGIC AND CLINICAL EFFECTS OF LOW-FREQUENCY MAGNETIC AND ELECTRIC FIELDS.

(E.) Llauro, J. G. (Marquette Univ., Milwaukee, Wisc.), A. Sances, Jr., and J. H. Battocletti. (Springfield: C. C. Thomas, 1974), pp. ix-xi.

Ever increasing amounts of man made emanations from EM sources are introduced into the environment, often without consideration of harmful biological effects. As the number of sources increases, the potential for damage also grows. Evolution has equipped man with a reasonable tolerance for this radiation, but little quantitative information is available regarding the effects of these mechanisms upon living organisms. For this reason, a forum was assembled with a wide range of expertise in industry, government and in the life and physical sciences. The current state of

knowledge on the effects of static and slow changing magnetic and electric fields on the communication processes in humans, animals, and plant life was examined in a symposium and series of workshops. This meeting was sponsored by the U.S. National Science Foundation in conjunction with the Neuroelectric Society, the International Institute for Medical and Biological Engineering, Marquette University, and The Medical College of Wisconsin. Twenty-three papers, most of which are abstracted in this issue of *Biological Effects of Electromagnetic Radiation* (CL 0632 - CL 0655), were presented and four workshops were held. These workshops included criteria and recommendations for a comprehensive research plan in each area to be generally applicable for research, industrial, and government use. (No references)

0632 ELECTROSTATIC FIELDS, ELECTROMAGNETIC FIELDS, AND IONS - MIND/BODY/ENVIRONMENT INTERRELATIONSHIPS. (E.) Beal, J. B. (World Inst., New York, N. Y.). *Biologic and Clinical Effects of Low-Frequency Magnetic and Electric Fields*, ed. J. G. Llauro, A. Sances, Jr., and J. H. Battocletti (Springfield: C. C. Thomas, 1974), pp. 5-20.

The relationships between man and his EM environment are discussed. At a basic level, the cell wall is found to be folded and convoluted in a manner to serve as a semi-conductor. Cell components include organic semiconductors like liquid crystals that are hypersensitive to temperature changes, magnetic and electric fields, stress, ionizing radiation, and contamination. Many cells have a double outer membrane which functions as a capacitor with the characteristics of a leaky dielectric. At low frequencies, the cell membrane permeability to ions is enhanced, promoting electrochemical interactions. Detection of minute magnetic and ES fields which accompany biological activity may lead to such things as monitoring effects of the mind on physiological processes and early diagnosis of specific disease. The living cell is subject to the influence of EMFs that may induce a complex system of currents and act as indicators of environmental conditions. Any mechanism which, for example, disrupts the highly structured biowater within the cell will certainly disrupt the biological transfer of electrons. At a larger level, the brain receives input from the nervous system by means of electrical pulse generation and transmission through the nervous system. ESFs can influence the rate of generation by the nerves and a positive ESF can improve such things as brightness discrimination and alertness. One of the most sensitive areas of the brain to EMF effects is the hypothalamus. Damage to this area can increase sensitivity to field changes many times. Some aspects of the brain's electrical activity are related to intelligence, as sensory stimulation causes nonrandom change in EEG activity. Thus, our biorhythms react to EM and ES fields, LF radiation, ions and other unknown factors. (43 references)

0633 SOURCES, PROPAGATION, AMPLITUDE AND TEMPORAL VARIATION OF EXTREMELY LOW FREQUENCY



(0-100 Hz) ELECTROMAGNETIC FIELDS. (E.) Polk, C. (Dep. Electr. Eng., Univ. Rhode Island, Kingston). *Biologic and Clinical Effects of Low-Frequency Magnetic and Electric Fields*, ed. J. G. Llauro, A. Sances, Jr., and J. H. Battocletti (Springfield: C. C. Thomas, 1974), pp. 21-48.

Information about natural background noise in the  $10^{-3}$  Hz to 100 Hz frequency region is given. Nothing in this region of natural origin is thought to have any biological effect, and no such effects have ever been satisfactorily established. This is not surprising in terms of the extremely low amplitude of natural ELF noise in comparison with man-made noise and with the amplitude of steady geomagnetic and atmospheric electrical fields. The intensity of earth's magnetic field is not constant, even in the absence of solar disturbance, but exhibits a 'solar quiet daily variation' (Sq) about a 24 hr periodicity. This Sq changes with latitude and season and is also affected over long periods by trapped particles in the ionosphere. The largest variation occurs over the geomagnetic equator. In any attempt to relate biological changes to natural magnetic disturbances, it is necessary to consider that major magnetic storms are accompanied by other geophysical phenomena like meteorological effects and variation in cosmic rays which could also have biological effects. In the absence of local disturbances, the steady fair weather electric field would be essentially constant. However, temperature, relative humidity, ionized pollutants, naturally occurring ions, and ordinary clouds, as well as thunder clouds, can profoundly affect the electric field at ground level. Large deviations from the fair weather field are expected in the presence of fog, rain, or substantial clouds. At locations where local effects are minimal, a curve of diurnal variation is obtained with a minimum 18% below the mean and a maximum 15% above. Natural fluctuations of the geomagnetic field and the resulting earth currents called micropulsations also occur with periods between 600 sec and 0.2 sec. In measuring frequencies below 100 Hz, man-made noise must be suppressed as this is almost always much larger than natural fields and may frequently mask the noise due to natural phenomena. (77 references)

0634 CRITICAL REVIEW OF THE BIOLOGICAL EFFECTS OF ELECTRIC AND MAGNETIC FIELDS. (E.)

Kaufman, G. E. (Sch. Med. Dent., Univ. Rochester, N. Y.) and S. M. Michaelson. *Biological and Clinical Effects of Low-Frequency Magnetic and Electric Fields*, ed. J. G. Llauro, A. Sances, Jr. and J. H. Battocletti (Springfield: C. C. Thomas, 1974), pp. 49-61.

A review of the biological effects of stationary electric and magnetic fields and of alternating fields with frequencies up to 100 Hz is presented. In non-contact electric fields, low frequency exposure may give rise to dangerous current densities in the body which are proportional to field strength and frequency. Soviet literature indicates biological effects of stationary and low frequency electric fields including physiological and morphologic

changes. Neither animal experimentation nor clinical studies have provided evidence for a harmful effect of exposure in Western studies. Magnetic fields do exhibit biological effects, but it appears that man can tolerate short exposures to high magnetic fields without ill effects. Changes in the ECG and EEG of test animals have been seen, but the significance of these changes has not been established. Over a long period, there may be a gradual accumulation of physical and biochemical imbalances including growth retardation, hematologic changes, morphologic changes, and delayed wound healing. This may be due to inhibition of mitosis, and is of possible use in cancer therapy. Possible genetic effects have not been fully explored. A set of safety standards for human exposure to magnetic fields has been recommended, with whole body exposure of up to 2000 G for short periods of time allowed. The question of very weak fields needs to be studied due to lack of knowledge of the effects on man traveling in space and scientific interest in the possible physiologic role of the normal geomagnetic field. Little is known about the biological effects of alternating magnetic fields. (38 references)

0635 ELECTRIC AND MAGNETIC FIELDS PRODUCED BY COMMERCIAL POWER SYSTEMS. (E.) Miller,

D.A. (IIT Res. Inst., Chicago, Ill.). *Biologic and Clinical Effects of Low-Frequency Magnetic and Electric Fields*, ed. J. G. Llauro, A. Sances, Jr., and J. H. Battocletti (Springfield: C. C. Thomas, 1974), pp. 62-70.

The nature of electric and magnetic fields produced by commercial power systems is described and values of typical fields are reported. In the U.S., the ordinary commercial power frequency is 60 Hz, with specialized applications at 16-2/3 and 25 Hz. Electric energy is sent to substations by large transmission lines which operate at several hundred thousand volts line-to-line. Transmission is done with 3 phase circuits employing at least 3 wires balanced in that at each instant of time the sum of the current flow in a given direction along all 3 conductors is zero. Distribution substations feed the distribution lines used to send power to the customers. At the customer's location, a distribution transformer steps down the voltage to 120-240 V. The current flow gives rise to magnetic and electric fields in the earth and the differences of potential give rise to electric fields in the air surrounding the conductors. The values reported are typical of fields which have been present for several generations with no apparent ill effects. (6 references)

0636 PSYCHOLOGICAL EFFECTS OF MAGNETIC AND ELECTRIC FIELDS. (E.) Wilson, A. S.

(Psychophysiol. Res. Lab., VA Center, Wood, Wisc.). *Biologic and Clinical Effects of Low-Frequency Magnetic and Electric Fields*, ed. J. G. Llauro, A. Sances, Jr., and J. H. Battocletti (Springfield: C. C. Thomas, 1974), pp. 71-80.

A review of research on the effects of EMR on complex higher order behavior was undertaken. Psychological research on the influence of magnetic and electrical energy was found to have identified few tangible effects. The experimental efforts lacked a systematic approach to the examination of the variables involved, and the research has so far produced no data suggesting that a profound psychological hazard may be developing. (19 references)

- 0637 PROJECT SANGUINE: OVERVIEW AND STATUS OF THE NAVY'S ELF COMMUNICATIONS SYSTEM CONCEPT. (E.) Baker, R. E. (U.S. Naval Electron. Syst. Command, Washington, D.C.). *Biologic and Clinical Effects of Low-Frequency Magnetic and Electric Fields*, ed. J. G. Llauro, A. Sances, Jr., and J. H. Battocletti (Springfield: C. C. Thomas, 1974), pp. 83-90.

Sanguine is a proposed reliable and survivable communication system for transmitting messages to submerged submarines and other U.S. Forces from a single transmitting location. The system will radiate ELF energy at less than 100 Hz. It has advantages of low atmospheric attenuation, low sea water attenuation and slight effect by disturbed propagation path. The transmitting antenna will excite EM waves in the spherical cavity bounded by the ionosphere and the earth's surface. The vertically polarized electric field has a small horizontal component which propagates downward through sea water and can be sensed by an electric field submarine antenna. The principal components are the insulated antenna cables, transmitter equipment, and terminal grounds. Messages from the Wisconsin Test Facility utilizing  $<1/2$  W radiated power have been received in Norway and by a submerged submarine. An Environmental Compatibility Assurance Program (ECAP) was set up to assure minimal adverse environmental impact during construction and operations. The electric field produced by Sanguine is no greater than that produced by commercial power lines, and no harmful effects have yet been seen. (No references)

- 0638 BIOLOGICAL RESEARCH FOR EXTREMELY LOW FREQUENCY COMMUNICATIONS SYSTEMS. (E.) Rozzell, T. C. (Off. Naval Res., Arlington, Va.). *Biologic and Clinical Effects of Low-Frequency Magnetic and Electric Fields*, ed. J. G. Llauro, A. Sances, Jr., and J. H. Battocletti (Springfield: C. C. Thomas, 1974), pp. 91-97.

There is concern about possible side effects on biological systems and the environment from ELF radio waves. The Sanguine antenna is such an ELF transmitter. It is not known whether the ELF electromagnetic radiation produced at the low levels expected for a Sanguine system would produce measurable adverse reactions in biological systems. None of the studies made by the U.S. Navy have indicated this. The Navy's research program allows exposures to be made at field strength levels equal to and up to 100 times greater than the expected Sanguine levels. The

experiments include animals, plants, and humans, and a continuing review of literature and research will be made to ensure minimal risk of biotic disturbances. (4 references)

- 0639 EVALUATION OF THE HEALTH OF PERSONNEL WORKING NEAR PROJECT SANGUINE BETA TEST FACILITY FROM 1971-1972. (E.) Krumpe, P. E. (Naval Med. Res. Unit No. 4, Great Lakes, Ill.) and M. S. Tockman. *Biologic and Clinical Effects of Low-Frequency Magnetic and Electric Fields*, ed. J. G. Llauro, A. Sances, Jr., and J. H. Battocletti (Springfield: C. C. Thomas, 1974), pp. 98-122.

Problem-oriented medical data were established for 24 personnel at Project Sanguine Beta Test Facility in 1971. These subjects were paired with control volunteers from Great Lakes, Ill. In follow-up examinations 1 yr later, 12 Sanguine employees were available and 9 of these matched controls for comparative analysis. At each exam, detailed medical histories and physical exams were performed along with specialized studies. These included psychometric testing; ECG; Masters test; EEG; electromyogram; nerve conduction velocity; slit lamp eye exams; chest, abdominal, and skull x-rays; audiogram; gynecologic evaluation of women; and blood, serum, urine, stool, and semen specimen exams. The test subject moved freely into and out of the EMFs, and the influence of shielding by buildings and vehicles was not measured. Periodic exposure to intense fields while working at or near the antenna and terminals was an uncontrolled variable also. Trends toward increasing or decreasing values during the interexamination period were tabulated; however, no effect due to the facility on test subjects was noted. No medical problems attributable to exposure were noted and no significant changes in constitutional symptoms, the endocrine system, neuromuscular, ophthalmologic, cardiac, or hematologic exam, or psychological profiles were seen. No evidence of the neuroathenic syndrome was noted. In conclusion, no significant differences were observed between test and control subjects and the Sanguine employees did not appear to suffer any ill effects attributable to their ELF exposure during the 1 yr period studied. (22 references)

- 0640 MICROWAVE RADIOMETRIC TECHNIQUES: A MEANS TO EXPLORE THE POSSIBILITY OF COMMUNICATION IN BIOLOGICAL SYSTEMS. (E.) Bigu del Blanco, J. (Dep. Anat., Queen's Univ., Kingston, Ontario, Canada) and C. Romero-Sierra. *Biologic and Clinical Effects of Low-Frequency Magnetic and Electric Fields*, ed. J. G. Llauro, A. Sances, Jr., and J. H. Battocletti (Springfield: C. C. Thomas, 1974), pp. 123-136.

Biological systems are sophisticated generators and receptors of different energy forms which interact among themselves and with their surroundings. They generate EM, electric, and magnetic fields. Because of the possible role of EMFs in bioinformation transfer, the contribution of MW radiometry to the



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question of information transfer between biological systems is studied. Radiometry is based on the fact that all bodies in the known physical universe emit EMR, and a reasonable amount of this radiation is in the MW region. Living systems have both a thermal emission spectrum and a nonthermal spectrum made up of a number of well-defined lines of emission and absorption due to discrete sources and sinks of EMR in the body. In a pilot study an X-band MW radiometer was constructed and experiments were conducted at 8.95 GHz. Natural MW emissions from human and animal subjects were measured. Results showed a large increase in natural MW emission relative to the background, corresponding to different states of stress or changes in the emotional, physiological, and pathological state. There are potential applications to biology and medicine as, for example, MW characteristics of damaged and malignant tissues are different from normal ones. MW radiometry may be a powerful tool in biocommunications as well. (10 references)

- 0641 EXTRA LOW FREQUENCY (ELF) ELECTROMAGNETIC RADIATION AS A BIOCOMMUNICATIONS MEDIUM: A PROTEIN TRANSRECEIVER SYSTEM. (E.) Cole, F. E. (Alton Ochsner Med. Found., New Orleans, La.) and E. R. Graf. *Biologic and Clinical Effects of Low-Frequency Magnetic and Electric Fields*, ed., J. G. Llaurodo, A. Sances, Jr. and J. H. Battocletti (Springfield: C. C. Thomas, 1974), pp. 137-146.

Questions still arise as to the type, availability, and operation of various forms of energy necessary for polypeptide synthesis on primitive earth. The theory has been presented that enormous amounts of EM energy arose from an ELF dependent, planetary resonance phenomenon. Sensitivity of biological systems to this spectral region would result as a consequence of this ELF dependent spontaneous generation of life, and this sensitivity would be augmented by eons of evolution. This evolutionary pressure is postulated to have fostered the development of a protein-mediated transreceiver system exquisitely sensitive to perturbations in this region. On earth, the molten core-ionosphere was envisioned to have functioned as an ELF oscillator with a 10 Hz eigenfrequency. The high intensity resonant magnetic fields penetrated the molten core, enhancing the fluctuating component of the earth's primary magnetic field and permitting an exponential increase in the strength of the 10 Hz field. An enormous electric disturbance would occur, permitting the formation of boundless quantities of organic compounds when the surface temperature was below 100 C. Evidence exists which suggests that the relationship between life and ELF fields still functions, hinting that a mechanism resides in the organism at the molecular level capable of interpreting and transmitting these signals. Such a transreceiver mechanism could be sensitive to and transmit almost unmeasurable quantities of radiated energy. The protein molecule could function as this transreceiver. Since protein makeup would have had to conform to the dynamics of the 10 Hz field, higher levels of construction would have EM structure reflecting these orienting forces and would be ex-

tremely sensitive to ELF electromagnetic fields. Subsequent evolution would enhance the fidelity of transmission and reception, especially between generically related forms. (10 references)

- 0642 COMMUNICATION IN BIRD FLOCKS: AN ELECTRO-MAGNETIC MODEL. (E.) Heppner, F. H. (Dep. Zool., Univ. Rhode Island, Kingston) and J. D. Haffner. *Biologic and Clinical Effects of Low-Frequency Magnetic and Electric Fields*, ed. J. G. Llaurodo, A. Sances, Jr., and J. H. Battocletti (Springfield: C. C. Thomas, 1974), pp. 147-162.

A hypothesis is presented to explain the apparently synchronous movements of certain species of birds while flying in flocks. Cluster formation characteristics of blackbirds and some small shore birds are composed of birds flying in close order with the flock in a spherical shape. Their movements are highly coordinated. In one 34 sec sequence of New York starlings the birds reversed directions 7 times, and each time all birds had changed directions within 1 sec. In another segment of rock doves most birds were setting their wings within 1/48 sec in preparation for a gliding turn. In a third film of mixed blackbirds, the signals for turning were undetectable so presumably reached all birds in less than 1/70 sec as the film was taken at 70 frames/sec. Two possible cases for leadership are considered: (1) a leader anywhere within the flock capable of transmitting a signal to the flock from any position within range of his transmission, or (2) a leaderless flock with all birds acting in concert as a 'superindividual'. Since the second case goes beyond any present evidence, the first possibility is tentatively accepted. The birds could conceivably communicate by sound, light, or EM systems. However, sound travels too slowly to reach all members of a flock essentially simultaneously, and it is doubtful whether sound could be heard over the background noise. Visual signals are not practical in a large flock where birds in the center would block the sight of birds on the periphery. If a visual relay system were employed, one would expect to see a wave of turning pass through the flock which is a function of the flock density and bird reaction time. The EM system would operate by the detection of an induced EMF surrounding the leader produced by electrical activity in the brain and neuromuscular system. It has been shown that bird feathers can act as EM detectors so the remaining problem is one of transmission. The leader bird may be able to develop currents in the long bones of his wings which could be transmitted to the rest of the flock. As a turn is made, differential stress would alter the transmitted signal which would furnish directional information to the other birds. The nervous system as a whole may be able to act as an antenna. The problem remains to prove the links experimentally. (24 references)

- 0643 LABORATORY SIMULATION OF EXTREMELY LOW FREQUENCY ELECTRIC AND MAGNETIC FIELDS. (E.) Valentino, A. R. (IIT Res. Inst., Chicago, Ill.). *Biologic and Clinical Effects of Low-Frequency Magnetic and Electric Fields*, ed. J. G. Llaurodo, A.



Sances, Jr., and J. H. Battocletti (Springfield: C. C. Thomas, 1974), pp. 163-171.

The mechanisms by which the E-field induces current in organisms under test depend on differences in conductivity and the geometrics involved. Examples are given to establish a uniform electric field in a conductive media. The same magnitude and distribution of currents must be produced within the organism as those that would result from its exposure to the fields in the natural habitat. The amount of current which will flow through an animal will depend upon the electric field, separation of the two points of contact with earth, and the total resistance of the current path. Except for the level of the electric field and current flow, all other features of an electric field simulator must be identical for test and control samples. To establish a uniform magnetic field over a working volume simple magnetic field generating structures such as solenoids, Helmholtz coils, and multicoil structures have to be used. (No references)

- 0644 REINFORCEMENT OF TRANSIENT BRAIN RHYTHMS BY AMPLITUDE-MODULATED VHF FIELDS. (E.) Bawin, S. M. (Brain Res. Inst., Univ. California, Los Angeles), R. J. Cavalas-Medici, and W. R. Adey. *Biologic and Clinical Effects of Low-Frequency Magnetic and Electric Fields*, ed. J. G. Llauro, A. Sances, Jr., and J. H. Battocletti (Springfield: C. C. Thomas, 1974), pp. 172-186.

Effects of very weak fields on changes in learned or spontaneous behavior and interaction with auditory responses and with brain evoked responses are studied. Experiments with VHF (147 MHz), low intensity ( $\leq 20$  V/m) electric fields, amplitude-modulated over a wide, low frequency range (0-20 Hz) were conducted on chronically implanted, untrained cats at EMF intensities of about  $1 \text{ mW/cm}^2$ . The cats were implanted with bipolar electrodes in the caudate nucleus, centrum medianum, hippocampus, and presylvian gyrus. Eye movements were also monitored. Specific EEG patterns were selected in movement free epochs in different brain locations during two control sessions. The animals were trained for 10 sessions before being submitted to extinction until the return to control levels of performance. They were reconditioned for 4 sessions, then divided into two groups: (1) four animals were overtrained for 6 days then resubmitted to extinction in the absence of fields; (2) three animals were irradiated during overtraining and extinction. Performances were assessed by visual and spectral analyses. A group of untrained animals was used to test the effectiveness of the modulated VHF fields. All animals reacted similarly to the initial conditioning and subsequent extinction, and exhibited similar relearning curves up to day 5. Control cats maintained regular levels of performance during the 6 overtraining sessions but never exceeded their previous achievement. Extinctions were again rapid. The irradiated animals displayed irregular high performances and eventually all levels were equal or superior to the highest scores obtained during the first conditioning. During extinction they continued to perform with irregular, high performances

during a minimum of 45 successive days before dropping back to operant levels. Subtle EEG changes took place with frequency bandwidths contracting into sharp peaks at the dominant frequencies of the responses. It is thought that the effects seen were the results of genuine biological transductions in the CNS rather than generalized thermal effects or artifactual injections of field voltages via electrodes. All effects were restricted to anatomically localized rhythms, frequency related to the assigned modulations, suggesting that the modulation frequency was indeed responsible for the EEG changes seen in all irradiated animals. The hypothesis is presented that amplitude modulated VHF fields can under these circumstances act as effective, contingent reinforcers. The mechanism of interaction is unknown, but a direct action of the fields on the CNS is favored with a working hypothesis based on the concepts of a 'greater membrane of brain cells.' (54 references)

- 0645 INSTRUMENTATION TECHNIQUES FOR MEASURING THE EFFECTS OF ELECTRIC AND MAGNETIC FIELDS ON INSECTS IN MOTION. (E.) Ferris, C. D. (Bioeng. Program, Univ. Wyoming, Laramie) and S. D. Hakes. *Biologic and Clinical Effects of Low-Frequency Magnetic and Electric Fields*, ed. J. G. Llauro, A. Sances, Jr., and J. H. Battocletti (Springfield: C. C. Thomas, 1974), pp. 187-201.

Instrumentation designed and constructed to examine the behavioral response of restrained and unrestrained insects subjected to electrical, magnetic, and EM fields is described. Common houseflies (*Musca domestica*) were used in the two experimental systems reported here. One system was designed to monitor an unrestrained colony of flies in an induced electric field while simultaneously comparing activity of the colony in a field free region. This system was a free flight enclosure with one region exposed to an electric field and a second region kept free of fields. A light sensing diode matrix was constructed on the floor of the enclosure and a light source formed the ceiling. When an insect intersected a vertical line between a light sensor and the plane of light, the intersection was observed and counted. A set of electrodes with appropriate power supplies established a field over half the matrix and a set of dummy electrodes was mounted across the other half. Fields of 5000-10,000 V/m were applied and the colony's activity recorded. The insects preferred the region of the electric field in a ratio of approximately 2:1. Activity was also related to time of day, even though light, temperature, and humidity were constant. The second system was designed to determine if there was any obvious effect on the wing beat characteristics of a tethered fly when subjected to an intense electric field. The insects were anesthetized, mounted on a splinter of bamboo with bayberry wax, and subjected to 1000-2000 V/m electric fields. Optical reflection from the wings using a photo diode which responded to the wing beat frequency was used. No observed change in frequency was observed between free and induced field experiments. In the presence of a magnetic field of 6000 gauss, the wing beat signal amplitude increased with a definite alteration of the spectral components. When free flight behavior was measured in a magnetic

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field, there was little correlation between behavior and field free or induced periods. The experiments are designed to show the feasibility of the instrumentation developed and no experimental conclusions are drawn. (16 references)

- 0646 CONTROL OF VISUAL FATIGUE BY MEANS OF DC AND AC ELECTRIC FIELDS. (E.) Sugiyama, S. (Kwansei Gakuin Univ., Nishinomiya, Hyogo, Jap.). *Biologic and Clinical Effects of Low-Frequency Magnetic and Electric Fields*, ed. J. G. Llauro, A. Sances, Jr., and J. H. Battocletti (Springfield: C. C. Thomas, 1974), pp. 202-207.

The author had previously found that visual function could be artificially depressed or facilitated by controlling the frequency of photic stimulus given to the eye. The visual threshold, represented by the CFF (critical flicker frequency), can be increased or decreased by control of the frequency component of the photic stimulus, indicating that the central nervous function is directly related to the frequency of light. It was found that CFF could be controlled in a facilitative or inhibitory way according to the polarity of a DC high voltage field, and that AC fields influenced the CFF. In current experiments, the effect of the frequency component of the photic stimulus on the CFF was examined. The CFF was already under the influence of AC and DC positive and negative electric fields. In the first experiment it was found that the inhibitory effect of a flickering light stimulus (CFF - 6 Hz) was neutralized by an AC (15 kV) electric field, indicating that fatigue of the visual system could be avoided by exposing the subject to an AC field. In the second experiment the cancellation effects of photic (CFF  $\pm$  6 Hz) and DC ( $\pm$  15 kV) electric field stimuli was investigated. No cancellation was seen, indicating that the photic and electric field stimuli whose directions were opposite always produce an inhibiting state of function of the visual system. In the third experiment, possible enhancement of effects produced by photic and electric field stimuli with the same directions were studied. Enhancement of the inhibitory effect was seen, but no enhancement of the facilitative effect was found. Thus, the visual system is influenced by an electric field. An AC field can neutralize excessive functioning caused by photic inhibitory stimulus. An inhibitory DC field can enhance inhibitory states caused by photic inhibitory stimulus, but does not cancel effects when photic and electric field stimuli of opposite direction are used. (2 references)

- 0647 A WESTERN VIEW OF ACUPUNCTURE. (E.) Shealy, C. N. (Pain Rehabil. Cent., La Crosse, Wisc.) and A. Prieto, Jr. *Biologic and Clinical Effects of Low-Frequency Magnetic and Electric Fields*, ed. J. G. Llauro, A. Sances, Jr., and J. H. Battocletti (Springfield: C. C. Thomas, 1974), pp. 211-219.

No correlation of neurophysiological pathways has been made with appropriate acupuncture points; how-

ever, such interactions are being studied. Investigation of the nervous systems has confirmed the possibility that almost all pathological process can be produced by some form of brain or nervous stimulation. Disease processes are influenced by psychosomatic distress. The severity of symptoms and physical changes can be influenced by diet, heredity, drugs, toxins, infectious agents, etc. No single factor causes any disease. A variety of therapeutic aids can restore balance and health. Acupuncture plays a role as a safe treatment in trained hands and offers one method which aids in therapy. (21 references)

- 0648 A SCIENTIFIC EXPLANATION FOR THE RATIONALE OF ACUPUNCTURAL ANALGESIA. (E.) Kroger, W. S. (Inst. Compr. Med., Beverly Hills, Calif.). *Biologic and Clinical Effects of Low-Frequency Magnetic and Electric Fields*, ed. J. G. Llauro, A. Sances, Jr., and J. H. Battocletti (Springfield: C. C. Thomas, 1974), pp. 220-226.

As yet no rationale for acupuncture has been validated. Many successful surgical operations have been performed in China with use of acupunctural analgesia (A.A.). There are subtle effects from the cultural factors particular to China, a regimented society, which aid in A.A.'s success there. Acupuncture becomes a kind of operant conditioning. In China, a dry run of an operation is often performed by the surgical team. Such preconditioning (autogenic training) helps to eliminate fear and tension. It helps to block the pain impulses from reaching the higher sensorium. The twirling needles supplant verbal or nonverbal suggestions used by hypnotherapists. There is no proof for the meridians or spots. Acupuncture in the environment in which it is used is the method of choice. More restraint should be used in regarding it as a qualified method in the U. S. (17 references)

- 0649 PHYSIOLOGIC EFFECTS OF CEREBRAL ELECTROTHERAPY CURRENTS. (E.) Rosenthal, S. H. (Univ. Texas Med. Sch., San Antonio) and D. F. Briones. *Biologic and Clinical Effects of Low-Frequency Magnetic and Electric Fields*, ed. J. G. Llauro, A. Sances, Jr., and J. H. Battocletti (Springfield: C. C. Thomas, 1974), pp. 227-230.

In treatment of patients with cerebral electrotherapy (CET) many experienced a transient mild euphoria and/or marked increase in sexual libido during the course of treatment. This suggests that CET may act by direct stimulation of the hypothalamus and/or pituitary area and may cause hormonal and biochemical changes. A series of pilot hormonal screening tests, including evaluation of serum thyroxine and serum T-3 resin uptake and 24 hr urine catecholamines and 17-ketosteroids, were performed. CET was given daily for 30 min at a frequency of 100/sec and 1 msec pulse duration. Serum thyroxine and T-3 resin uptake level were drawn on 41 subjects (20 males, 21 females) prior to their first treatment and following 4 standard



treatments. A definite transient rise in serum thyroxine was observed, but no significant change in T-3 resin uptake was seen. Of 20 males, 10 had rises of 0.5  $\mu\text{g} \%$  or more while 10 had no appreciable change. For 21 females the number of positive and negative changes was not appreciably different. Six males under 40 yr old were used in a study to measure 24 hr urinary catecholamines and 17-ketosteroids. Twenty-four hr urines were collected prior to beginning a course of CET and repeated 1 wk later after a series of 5 CET. All 6 subjects showed increases in urinary catecholamines, with the average reading rising from 23.9 to 48.7  $\mu\text{g} \%$ /24 hr ( $p \leq 0.02$ ). The average levels of 17-ketosteroids rose from 18.5 to 25.4 ng/24 hr. These studies indicate the presence of definite physiologic changes and suggest the possibility of a simple nontraumatic hypothalamic function test for neuroendocrinologists. Additional studies are underway. (4 references)

0650 SURFACE ELECTRICAL STIMULATION (TRANSCUTANEOUS) FOR THE RELIEF OF PAIN. (E.)

Burton, C. (Temple Univ., Philadelphia, Pa.) and D. Maurer. *Biologic and Clinical Effects of Low-Frequency Magnetic and Electric Fields*, ed. J. G. Llaurodo, A. Sances, Jr., and J. H. Battocletti (Springfield: C. C. Thomas, 1974), pp. 231-240.

A transcutaneous stimulator and electrode system was developed that allowed a high degree of pain relief. In designing the system, the major concerns were safety, efficacy, human engineering, reliability, and cost. The electrode system which was developed consisted of a silver loaded acrylic emulsion painted on the skin. While wet, a small carbon impregnated silicone pad was placed over the paint. A small connector pin could be inserted into a tail in the pad when dry. The epiconductive system is a low impedance, highly conformable, low profile transcutaneous electrode which is hypoallergenic. In tests on over 100 chronic intractable pain patients with various etiologies, the system had value in relief of pain. (11 references)

0651 FILTERED VERSUS UNFILTERED RF ENERGY FOR NERVE STIMULATION. (E.)

Friedman, H. (Medtronic, Inc., Minneapolis, Minn.) and T. Williams. *Biologic and Clinical Effects of Low-Frequency Magnetic and Electric Fields*, ed. J. G. Llaurodo, A. Sances, Jr. and J. H. Battocletti (Springfield: C. C. Thomas, 1974), pp. 241-251.

This study was conducted to determine if the square waveform, used to stimulate peripheral nerves, is necessary. Four different waveforms were tried experimentally: unfiltered and unrectified RF burst, RF half wave rectified and unfiltered, square wave rectified and filtered, and RF full wave rectified and unfiltered. A bipolar lead was wrapped around the sciatic nerve of a dog. The Achilles tendon was exposed and released from its insertion on the dog's calcaneus. The tendon was wired to a strain gauge force transducer in such a position that the muscle and tendon contracted isometrically parallel to the

two bones of the lower leg. Constant voltage pulses stimulated the nerve, with a fixed monitored force of contraction, voltage, and current. Unrectified and unfiltered RF pulses were completely inadequate. The three rectified waveforms produced the same force of contraction if the average voltage remained the same, but the unfiltered waveform required 2-3 times more energy than the filtered one. On the other hand, filtering required an extra capacitor and using the unfiltered waveform reduced the size and cost of the receiver, increased reliability, and simplified manufacture. Long term testing is needed to determine the chronic effectiveness and safety of an unfiltered waveform on nerve tissue. (10 references)

0652 IN VIVO ELECTROPHYSIOLOGY OF TENDONS AND APPLIED CURRENT DURING TENDON HEALING.

(E.) Kappel, D. A. (Kansas Univ. Med. Cent., Kansas City), S. Zilber and L. D. Ketchum. *Biologic and Clinical Effects of Low-Frequency Magnetic and Electric Fields*, ed. J. G. Llaurodo, A. Sances, Jr., and J. H. Battocletti (Springfield: C. C. Thomas, 1974), pp. 252-260.

In hand and extremity injuries, tendon repair is basic. As tendons are almost entirely collagen, the strength of healed wounds parallels the orientation and organization of collagen bundles in the healing interface. Mongrel 25 kg dogs were anesthetized and the flexor profundus tendon in the first digit of each hind paw was isolated. Two electrodes were attached to each tendon 2 cm apart and electrical measurements were performed during relaxation, stretch, after transection and repair, and after wound closure. In some dogs the electrode wires were then attached to an asymmetrical square wave stimulator supplying 100 mV, 60 mV positive-40 mV negative at 1 Hz for 3 hr/day, 5 days/wk. Healing was evaluated with hematoxylin-eosin stain. Specific electrical properties in tendons previously seen *in vitro* were confirmed *in vivo*. Resting differences of potential of 7.5 mV were recorded along the longitudinal axes of the tendons. These resting potentials increased during active elongation and shortening and disappeared almost entirely when the tendons were severed. This effect may contribute to the realignment and eventual organization of collagen in the healing tendon. The change in the resting potential when the tendon is severed and repaired may be correlated with healing and return of strength and may serve as a guide for initiating rehabilitation. (6 references)

0653 WORKSHOP ON MAGNETIC-ELECTRIC FIELDS AND ENVIRONMENT. (E.)

Franklin, D. L. (Scripps Clin. Res. Found., La Jolla, Calif.) and J. B. Beal. *Biologic and Clinical Effects of Low-Frequency Magnetic and Electric Fields*, ed. J. G. Llaurodo, A. Sances, Jr., and J. H. Battocletti (Springfield: C. C. Thomas, 1974), pp. 321-328.

Four broad problem areas were identified as pertaining to magnetic-electric field frequencies from DC to the MW range. No priority could be established for any one area as they are closely interrelated,



and it was recommended that they be developed concurrently. Area one defines critical unsolved problems: the lack of instrumentation to measure field effects and the responses of biologic systems, the lack of detailed information on environmental effects particularly in regions other than the MW area, the lack of models and standards required by complex interacting variables, and the lack of educational and communication needs, including interdisciplinary curricula. Area two defines a priority list of problems: method development, establishment of a range of system variations, determination of physical mechanisms for variations, and definition of field effects on living systems. The third area identifies researchers and institutions capable of handling these problems and identifies qualifications needed in this research. Area four defines the criteria for evaluation of research proposals. These include competent researchers, evaluation of scientific merit of work, imaginative solutions, clearly defined alternatives, and judgment of whether special recognition of broad implications of the biologic effects of EM fields is present. (5 references)

- 0654 WORKSHOP ON SOURCES AND SAFE LEVELS OF ELECTRIC AND MAGNETIC FIELDS. (E.) Kahn, A. R. (Medtronic, Inc., Minneapolis, Minn.), D. A. Miller and E. Postow. *Biologic and Clinical Effects of Low-Frequency Magnetic and Electric Fields*, ed. J. G. Llauro, A. Sances, Jr., and J. H. Battocletti (Springfield: C. C. Thomas, 1974), pp. 329-333.

The development of society has paralleled the utilization of energy, much of which is in the form of electricity. It is necessary to examine the possible effects of the electric power distribution system and other sources of low level electric and magnetic fields on biological systems. Only that portion of the frequency spectrum below 1 kHz is considered. No substantial evidence has been given to show that low frequency electric fields produce any deleterious effects on humans, but the possible need for safety standards should be investigated. To do this, the first step is to find biological effects believed to be caused by these fields. Then the threshold of the effects in terms of frequency, power, and other unique characteristics should be determined, and the potential hazard to humans evaluated. The time course of the effect must be determined and a decision made in regard to safety standards of the EM field. A system of priorities of possible CM hazards is recommended: (1) high voltage 60 Hz electric fields; (2) high voltage DC electric fields; (3) 60 Hz magnetic fields produced by buried superconducting transmission lines; and (4) 16 2/3, 25, 50 and 400 Hz fields. Other areas to consider are airport magnetic detection systems and library and department store merchandise detection devices. If a biological effect does exist, it will be very subtle, so multiple stress experiments, psychological, and behavioral experiments are strongly recommended along with the use of human volunteers and chronic studies. Classical biological experiments should be used only after an effect is demonstrated to investigate the mechanism of interaction and to understand the influence of EMR on biological pro-

cesses. The lowest priority should be given to prospective and retrospective epidemiological studies. Joint biologic, behavioral, and engineering research teams are necessary for a successful program. (No references)

- 0655 WORKSHOP ON BIOLOGICAL EFFECTS OF ELECTRIC CURRENTS: ELECTRICAL STIMULATION AND THERAPY. (E.) Shealy, C. N. (Pain Rehabil. Cent., La Crosse, Wisc.) and A. Remond. *Biologic and Clinical Effects of Low-Frequency Magnetic and Electric Fields*, ed. J. G. Llauro, A. Sances, Jr., and J. H. Battocletti (Springfield: C. C. Thomas, 1974), pp. 334-337.

The widest chronic use of electric stimuli has been in the field of cardiac pacemakers, and the major concern in this technique is the lack of a standardized approach to their use. In other uses, electrical stimulation includes transcutaneous stimulation, which is at least partially effective in acute and chronic pain 75% of the time. Implantation of RF activated stimulators around peripheral nerves has had significant effectiveness in controlling pain, as has dorsal column stimulation. Brain stimulation by totally implanted units has shown intriguing success in the initial trials. Recommendations for further studies include: (1) hazards of long term stimulation; (2) evaluation of electrodes; (3) greater knowledge of effects of electrical energy; (4) systematic exploration of effects on body systems other than the nervous; (5) potential application to other disease processes; (6) better diagnostic tools for a variety of illnesses; (7) controlled randomized studies in the clinical use of electrotherapy; and (8) investigations to understand why therapy fails in some patients. (No references)

- 0656 INDUCTION THERMOCOAGULATION OF THE BRAIN--QUANTITATION OF ABSORBED POWER. (E.) Lin, J. C. (Dep. Rehabil. Med., Bioelectromagn. Res. Lab., Univ. Washington Sch. Med., Seattle). *IEEE Trans. Biomed. Eng.* BME-22(6):542-546, 1975.

RF electromagnetic field induction has been suggested as a simple, controllable, and repeatable technique to produce brain lesions. The procedure involves implanting a small metal seed in the brain and then introducing the head into an RF EM induction field. The seed is heated by the external field to produce a cerebral lesion. There is a lack of quantitative information regarding the amount of power absorption by the seed, the degree of tissue temperature elevation, and induction heating of other tissues of the body. A theoretical model was designed to study induction thermocoagulation as related to applied field strength, tissue electrical properties, and tissue geometry. The model is a cylindrical metal implant inside a spherical head containing homogeneous brain tissue throughout the sphere. Without any foreign object, the power deposition inside the sphere is a function of radius squared, increasing quadratically with distance away from the center. When a small cylindrical

metal implant is introduced, it may be assumed that the induced current in tissues surrounding the implant is unaltered. Calculations were made for an implant with a 1.0 mm radius and 5.0 mm length. Properties of the implant are that of 430 stainless steel and a 1 MHz operating frequency is chosen. The conductivity of the brain tissue is 0.263 mmho/m. It is found that power deposited in the metal implant is at least 2 orders of magnitude higher than that deposited elsewhere inside a 10 cm radius sphere. It is therefore possible to heat the therapeutic implant selectively. The power absorption throughout the head is highly dependent on location, so it may be possible to orient the head with respect to the applied magnetic field to shield heat sensitive areas. The problem of thermal consequences and tissue degeneration as a result of elevated temperature are not discussed. (12 references)

- 0657 NON-THERMAL RADIOWAVES AND GENETIC DAMAGE IN *DROSOPHILA MELANOGASTER*. (E.) Mittler, S. (Northern Illinois Univ., DeKalb). *Mutat. Res.* 31(5):316, 1975.

Adult *Drosophila* males were exposed to radiowaves produced at frequencies commonly used by amateur radio operators and various stages of spermatogenesis were tested for genetic damage. One group was exposed for 12 hr on the antenna of a 20 W transmitter to 146.34 MHz radiation at 62.5 V/m, and the second group was exposed for 12 hr to 29.00 MHz radiation from a 300 W transmitter. When testing for chromosome loss and non-disjunction, no genetic damage due to radiowave exposure was seen. (No references)

- 0658 A NOTE ON EMP SAFETY HAZARDS. (E.) Guy, A. W. (Bioelectromagn. Res. Lab., Dep. Rehabil. Med., Univ. Washington Sch. Med., Seattle). *IEEE Trans. Biomed. Eng.* BME-22(6):464-467, 1975.

EMP is a unique energy source which can produce far greater field strengths in man than can be produced by most sources of EM energy even though the absorbed energy density may be smaller. This is due to the relatively fast rate of change of field of the EMP. In this case, if concern is with limiting maximum field strength induced within the tissues, the time rate change of field is more important than the pulse-width. The rise time,  $t_m$ , is the most important in terms of magnitude of the induced field, peak absorbed power density, and the energy density deposition. At this time the EMP safety standard can be based on previous experiments with man's exposure to typical radar pulses under the limitation of the ANSI standard (10 mW/cm<sup>2</sup>) rather than relying on the definition of the upper limit of the electrical field intensity ( $E_m = 194/(t_m)^{1/2}$  V/m) which has appeared in the *Federal Register*. (4 references)

- 0659 MAGNETOTACTIC BACTERIA. (E.) Blakemore, R. (Woods Hole Oceanogr. Inst., Mass.). *Science* 190(4212):377-379, 1975.

Magnetotaxis, a bacterial response to magnetic fields, has been found in at least 5 morphologically distinct types of bacteria in the vicinity of Woods Hole, Mass. The cells were characterized by two chains of 5-10 electron-opaque crystallike particles found to be internal cell components. The crystallike particles were often found within intracytoplasmic unit membranes arranged as vesicles about the periphery of the cells. The tendency of these particles to clump when outside the cell is consistent with the possibility that they may be a permanently magnetic substance. Within the particles, iron was the predominantly detectable element. Freely suspended killed cells frequently formed chains of up to 10 cells which acted as a single dipole in response to changes in the position of a nearby permanent magnet. Studies of the behavior of living and dead cells in uniform and nonuniform fields should contribute to an understanding of the magnetotactic mechanism. (5 references)

- 0660 PERCUTANEOUS RADIOFREQUENCY DENERVATION OF SPINAL FACETS. (E.) Shealy, C. N. (Pain Rehabil. Cent., S. C., La Crosse, Wisc.). *J. Neurosurg.* 43(4):448-451, 1975.

A technique for RF localization and coagulation of articular nerves supplying the spinal facets, based on Rees' closed surgical procedure, was developed. Following localization of puncture points under fluoroscopy and local anesthesia, No. 12 gauge thin-walled needles were introduced and a thermistor electrode (19 cm x 1.2 mm diameter) was inserted through one of the guide needles. After radiographic and electrical confirmation of desired electrode position, the RF generator was activated and the lesion temperature was raised over a 1-2 min period to 80 C with maintenance for 150 sec. The procedure was repeated at other involved levels after which the patient returned directly to his room, rested for 2 hr, and was then encouraged to start spinal exercises. Pain relief was usually obvious at completion of the RF lesions. The 207 patients followed for at least 6 mon were divided into 3 groups: (1) 57 who were previously unoperated, (2) 60 who had undergone previous operations without fusion, and (3) 90 patients who had undergone operations with spinal fusion. Patients on follow-up were asked about how much of the time they had pain, severity of pain, inhibition of physical activity, drug usage, and personality effects. No neurological complications were seen in these patients. For those in group 1, 79% achieved relief of pain, 41% in group 2, and 27% in group 3. Most late failures had a return of pain within 1 mon after the procedure. The high failure rate in groups 2 and 3 is related to the extensive scarring, often coupled with arachnoiditis, seen after so much surgery. This procedure is simple and safe and offers relief when there is no comparable alternative therapy. (9 references)

- 0661 A CASE OF PROLONGED, REVERSIBLE DEMENTIA ASSOCIATED WITH ABUSE OF ELECTROCONVULSIVE THERAPY. (E.) Regestein, Q. R. (Div. Psychiatr., Dep. Med., Peter Bent Brigham Hosp., Boston, Mass.),

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B. J. Murawski, and R. P. Engle. *J. Nerv. Ment. Dis.* 161(3):200-203, 1975.

Confusion and amnesia following electroconvulsive therapy (ECT) usually lasts only a few weeks and clears completely thereafter. However, in some cases, memory disturbances may persist more than a year, particularly when large numbers of treatments are administered. There is much diversity of opinion about the number of ECT treatments indicated for psychiatric patients. A 57-yr-old housewife complained of abdominal and epigastric discomfort and insomnia. Her initiative deteriorated and she became inadequate at housework. Medical examination of the abdomen and upper GI tract were unrevealing and she was referred to a psychiatrist. ECT was given 3 times a wk for 2 mon, then 2 times a wk for 1 mon. She was discharged on amobarbitone and given ECT once a wk for 2 yr. She did no housework, slept, ate, and watched television all the time, had no initiative or spontaneity, and showed a profound memory deficit. Eventually an independent assessment was done despite warnings from her first psychiatrist, and ECT was stopped. She was reassessed monthly and drugs were gradually withdrawn. Over a period of months she began to converse, sensorium proved clearer, and fitful sleeping and pain returned. Eleven mon after cessation of ECT antidepressants were administered which relieved the remaining symptoms. Weekly ECT had caused a dense impairment in memory although lack of a clear history and mental status at the time of first presentation makes careful diagnosis of the original condition impossible. (18 references)

0662 SOME BIOCHEMICAL AND CYTOLOGICAL OBSERVATIONS ON THE EFFECT OF NONIONIZING (MICROWAVE) RADIATION. (E.) Dwivedi, R. S. (Dep. Bot., Howard Univ., Washington, D.C.), S. Ogunwuyi, and W. McCleod. *J. Cell Biol.* 63(2):90a, 1974.

The effects of 10 mW/cm<sup>2</sup> 2450 MHz continuous and pulsed radiation on rabbits were studied. Results showed a decrease in levels of lactate dehydrogenase (LDG), glutamic oxalacetic transaminase (GOT), and alkaline phosphatase over a 2 wk period of chronic radiation. Levels of  $\alpha$ -1 globulin and  $\alpha$ -2 globulin were elevated although total protein, albumin, and  $\beta$ -globulin remained constant. There were striking changes in the LDH isoenzymes of the serum and testes. Severe damage to testicular cells was seen, including complete degeneration of tubules and leydig cells. The damaging effects were at least practically reversible if the animals were allowed to recover for several wk. There was little difference in effects due to continuous vs pulsed radiation, indicating that damage was not only thermal. The results suggest that MW radiation is capable of producing serious alterations in the metabolism of various key proteins, especially after prolonged exposure. (No references)

0663 RECOMMENDATIONS FOR SPECIFYING EM WAVE IRRADIATION CONDITIONS IN BIOEFFECTS RESEARCH. (E.) Johnson, C. C. (Dep. Bioeng., Univ.

Utah, Salt Lake City). *J. Microwave Power* 10(3):249-250, 1975.

Bioeffects research data, in terms of irradiation conditions, must be presented in a form suitable for comparison and evaluation. It is recommended that radiation conditions be reported in terms of the average and the localized absorbed W/kg in the sample. With this data it will be possible to extrapolate meaningfully to man for direct use in reassessing safety standards. The specific absorption rate (W/kg) in the tissue,  $P_L$ , is given by  $P_L = (\sigma/2\rho) \bar{E} \cdot \bar{E}$  where  $\sigma$  is the tissue conductivity at the irradiation frequency,  $\rho$  is the tissue density, and  $\bar{E}$  is the electric field strength in the tissue. Conventionally W/kg is measured in tissue by calorimetry, using thermography techniques or making point measurements of temperature rises with nonperturbing temperature probes. If the rise is linear with time,  $P_L = 4186c\Delta T/\Delta t$  where  $C$  is the tissue specific heat in cal/g C,  $\Delta t$  is the duration of radiation in seconds, and  $P_L = W/kg$ . It is strongly recommended that irradiation conditions be reported in terms of average and local W/kg. This information may be inferred from the following data: (1) specification of the incident wave intensity in mW/cm<sup>2</sup> if the radiation is planewave with  $E/H = 377\Omega$ ; (2) description of specimen shape, dimensions, electric properties, and orientation with respect to  $E$  and  $H$ ; and (3) description of specimen irradiation apparatus, specimen placement, presence of reflecting objects, etc. W/kg is the only common ground by which biological effects research can be compared, evaluated and utilized intelligently in the establishment of an irradiation safety standard. (No references)

0664 NONINVASIVE MICROWAVE MEASUREMENT OF RESPIRATION. (E.) Lin, J. C. (Dep. Electr. Eng., Wayne State Univ., Detroit, Mich.). *Proc. IEEE* 63(10):1530, 1975.

A technique using MW radiation to measure respiratory movements of man and animals was developed. Radiation (10 GHz) from an X-band standard gain horn is directed toward the chest of the subject and the reflection is detected and compared to the transmitted wave to give respiratory information. The method is simple, noninvasive, and requires no contact with the subject. Problems such as skin irritation, restriction of breathing, and loose electrode connections are eliminated, and use of ratio measurements make oscillator frequency unimportant. (2 references)

0665 EFFECTS IN RODENTS OF A 1-MONTH EXPOSURE TO MAGNETIC FIELDS (200-1200 GAUSS). (E.) Nahas, G. G. (Dep. Anesthesiol. Pathol., Coll. Physicians Surg., Columbia Univ., New York, N.Y.), H. Boccalon, P. Berryer, and B. Wagner. *Aviat., Space, Environ. Med.* 48(9):1161-1163, 1975.

An investigation was performed on the effects of continuous exposure to 200-1200 G magnetic fields. Microscopic observations were made of the capillaries of the mesoappendix of rats exposed to a 500 G field,



and a systematic histopathological study was performed of the major organs of rats exposed to magnetic fields of 200-1200 G for one mon. Cages containing 3 rats each were placed in a median position between 2 magnets so as to obtain a homogeneous magnetic field around the cages. Three control rats and 3 groups of 3 rats were exposed to 500 G for 6, 12, and 30 days, resp. Following exposure, capillary circulation was observed *in vivo* in the mesoappendix using 160x magnification. These capillaries were normal and showed no intravascular thrombosis regardless of exposure duration. Four groups of rats were exposed for 28-32 days to 0, 200, 400, and 1200 G fields. They were weighed before and after exposure and 24 hr urine specimens were collected following exposure. Twenty-four hr after exposure, blood samples were taken and all animals were sacrificed. Rats exposed to the magnetic field gained significantly more wt than controls. This wt gain was apparently related to field intensity. Final wt of brain, thymus, spleen, kidney, heart, liver, and testes was also significantly higher in exposed rats. Adrenals, ovaries, and lungs had the same final wt in all groups. There was no alteration in the vascular bed, no intravascular thrombosis, and no pathology of the artery walls in any group. Pneumonitis was found in all groups, including controls, and spleen congestion was found in both control and experimental animals: 2/6 controls were congested, 2/4 exposed to 200 G, 2/5 at 400 G, and 5/5 at 1200 G. No alteration in adrenal glands, liver, gonads or CNS tissue was found. There were no significant changes in hematocrit, WBC count, hemoglobin, or coagulation time. Exposure to the highest field used in this study produced no casualty or apparent ill effects. Further studies are needed of the effects of low intensity fields on growth and development. (19 references)

0666 THERMAL PROFILES OF NATIVE AND MICROWAVE-IRRADIATED DNA. (E.) Varma, M. M. (Bio-Environ. Eng. Sci., Howard Univ., Washington, D. C.) and E. A. Traboulay, Jr. *Mutat. Res.* 31(5):334, 1975.

Swiss male mice were irradiated for 30 min at 1.7 GHz with a power density of 50 mW/cm<sup>2</sup> to test for chemical changes in testicular DNA. A difference was seen between control and irradiated mice when measuring hyperchromicity and melting temperatures of DNA, supporting the possibility that MW irradiation causes strand separation. Carefully controlled experiments are needed to determine the degree of genetic damage. (No references)

0667 EFFECT OF A UNIFORM MAGNETIC FIELD ON LEUCOCYTES. STUDY OF PHAGOCYTOSIS. (Fr.) Bellossi, A. (Fac. Med. Pharm., Dakar, Senegal), M. Duclos, and G. Bellossi. *Bull. Soc. Med. Afr. Noire Lang. Fr.* 19(2):192-195, 1974.

The effect of exposure to a uniform magnetic field on phagocytosis of nonviable cells of baker's yeast by leukocytes was studied in blood samples taken from 49 randomly selected, presumably normal black African males and from patients with a variety of

infections. The latter group included 25 patients with pyogenic bacterial infections, 30 with pulmonary tuberculosis, 29 with leprosy infections, 20 with measles, and 7 with cerebral malaria. Plasma containing leukocytes was exposed to a magnetic field ranging in intensity from 4700 to 6300 gauss (mean 5500 gauss) for 3 hr at a temperature about 4 C above room temperature. After exposure to the magnetic field, the phagocytic index (ratio of the number of phagocytized yeast cells to polynuclear neutrophils) remained unchanged in 13 and increased in 36 of the controls. No correlation was found between adhesiveness and phagocytosis. Among the patients, exposure to the magnetic field increased the phagocytic index in patients with pyogenic bacterial infections. The phagocytic index decreased significantly after exposure to the magnetic field in patients with pulmonary tuberculosis and cerebral malaria but not in those with leprosy infections. In patients with measles, the phagocytic index remained unchanged in 13 and decreased in 7 after exposure to the magnetic field. It is hypothesized that the magnetic field acts on DNA, particularly on regulatory genes. (9 references)

0668 COMBINED EFFECT OF A UNIFORM MAGNETIC FIELD AND NONIONIZING RADIATION ON LEUKOCYTES. (Fr.) Bellossi, A. (Fac. Med. Pharm., Dakar, Senegal), M. Duclos, and J. de Certaines. *Bull. Soc. Med. Afr. Noire Lang. Fr.* 19(3):251-253, 1974.

Blood, taken from 85 presumably healthy black African men, selected randomly, was added to heparin and allowed to settle at room temperature. Plasma containing WBC was placed in glass slides holding 2.5 ml and was covered with a cover slip to prevent evaporation. One of these slides was placed in a magnetic field measuring 4000 to 6700 gauss (mean 5000 gauss) for 3 hr at 6.5 C above room temperature. The control was heated to the same temperature. Both samples were then exposed to radiation from a mercury-vapor lamp (2302 to 11,286 Å) at 30 C for 30 min. Radiant energy, measured in the 2537 Å band, was 2.8 mW/cm<sup>2</sup>. A total and differential WBC was then performed on both samples and controls. The total WBC was significantly lower in samples exposed to UV radiation alone than in controls. In samples exposed to both the magnetic field and UV radiation, the decrease was of borderline significance. The differential WBC showed that these decreases were largely due to decreases in polynuclear neutrophils. No apparent changes occurred in polynuclear eosinophils, and there were too few polynuclear basophils and monocytes to draw any definite conclusions. These changes, which have previously been reported to occur in Caucasians, are attributed to changes in the structure of proteins and/or nucleic acids. (5 references)

0669 EFFECTS OF A UNIFORM MAGNETIC FIELD ON SERUM AND PLASMA. ELECTROPHORETIC STUDY OF THE PROTEINS. (Fr.) Bellossi, A. (Fac. Med. Pharm., Dakar, Senegal) and J. Demaille. *Bull. Soc. Med. Afr. Noire Lang. Fr.* 19(3):275-276, 1974.

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Blood or plasma samples, taken from randomly selected, apparently healthy, black African males, were divided into 3 parts. One was placed in a uniform magnetic field measuring 4350 to 5900 Oe (mean 5100 Oe) for 3 hr at temperatures of 25 to 33 C (mean 29.5 C). The second was placed in an oven at the same temperature, and the third served as a control. The 3 samples were subjected to electrophoresis on the same strip of Phoroslides Millipore with pH 8.6 veronal buffer having an ionic strength of 0.075 for 20 min at 100 V. After staining with scarlet S, protein determinations were performed densitometrically. Using this method, protein determinations were performed on 23 serum and 21 plasma samples. Except for the  $\beta$  band in plasma, which included  $\beta$ -globulins and fibrinogen, there were no significant differences between partial correlation coefficients obtained for samples exposed to the magnetic field and those heated in the oven. A comparison of the mean percentages of proteins revealed that all serum globulins decreased and serum albumin increased after exposure to the magnetic field. However, the  $\beta$  band was denser in the exposed plasma samples than in the controls, while no appreciable change occurred in the  $\alpha_1$  band. No differences were observed in migration of serum albumin. If an ellipsoidal model is hypothesized, the changes observed could be accounted for by a decrease in the asymmetry of serum globulins and an increase in the asymmetry of fibrinogen after exposure to the magnetic field.  
(5 references)

0670 PRELIMINARY STUDY OF THE EFFECT OF A CONSTANT MAGNETIC FIELD ON *PROTEUS MIRABILIS*.  
(Fr.) Belloussi, A. (Fac. Med. Pharm., Dakar, Senegal) and Castets. *Bull. Soc. Med. Afr. Noire Lang. Fr.* 19(3):342-345, 1974.

The ability of *Proteus mirabilis* to ferment glycerol, arabinose, ribose, xylose, galactose, glucose, fructose, trehalose, and N-acetylglucosamine was investigated in the API system 50 after application of a magnetic field measuring 3700 to 4500 gauss (mean 4150 gauss) for 2 hr at a mean temperature of 30 C. Controls were incubated for 2 hr at room temperature (mean 23.5 C). No statistically significant differences were found after 24 and 48 hr incubation in API system 50 tubes at 37 C. Fermentation of glycerol, D(-)-fructose, and ribose was initially more rapid in cultures exposed to a magnetic field, but fermentation of glycerol and D(-)-fructose was the same in experimental and control cultures and ribose fermentation occurred more slowly in experimental cultures after 48 hr. After 24 hr incubation, D(+)-xylose, galactose, and D(+)-trehalose fermentation proceeded more slowly in experimental cultures than in controls. After 48 hr, no differences were observed in the rate of xylose and galactose fermentation, while that of trehalose was slower in experimental cultures. The fermentation of D(-)-arabinose, D(-)-fructose, and N-acetylglucosamine proceeded at identical rates after 24 hr, but fermentation of D(-)-arabinose and D(-)-fructose was faster and that of N-acetylglucosamine was slower in experimental cultures after 48 hr. (11 references)

## 0671 EFFECT OF PULSED ELECTRICAL DISCHARGES IN MICROORGANISMS IN WATER. (Rus.)

Pavlovich, S. A. (Kalinin Med. Inst., USSR), G. P. Osipov, P. P. Tofilo, and M. I. Voronkina. *Gig. Sanit.* (8):110-111, 1975.

Suspensions of *Escherichia coli*, *staphylococcus aureus*, and *Bacillus anthracis* in sterile tap water were exposed to high-voltage (50 kV), pulsed (1-2/sec), electrical discharges (capacitance 0.1-0.3  $\mu$ F). Bacterial suspensions were placed in airtight, stainless steel cylinders with two openings: the operating electrode was immersed in one and the other was covered with a tube for a pipette so that samples could be removed after exposure to 1-120 successive pulsed discharges. These high-voltage, pulsed electrical discharges had an antibacterial effect. When a suspension containing 2 million *E. coli* in 1 ml tap water was exposed to one such discharge, 20% of the bacteria were killed; 10 impulses killed 84.6%, and 20 impulses killed all of the bacteria. *B. anthracis* was even more sensitive: one pulsed discharge killed 91% of the bacteria and 10 discharges killed all of them. Further experiments demonstrated that bacteria suspended in distilled water were more sensitive to these electrical discharges than those suspended in tap water, while bacteria suspended in saline solution were highly resistant. Exposure of river and tap water to high-voltage pulsed electrical discharges (capacitance 0.1  $\mu$ F) revealed that tap water was completely sterilized by 20 discharges, but it required 60 discharges to kill 92% of the bacteria in river water. This is attributed to the higher bacterial count in river water and to the high concentration of salts and organic impurities which greatly reduce the antibacterial action of high voltage, pulsed electrical discharges.  
(6 references)

## 0672 STUDY OF THE BIOLOGICAL EFFECTS OF PROLONGED EXPOSURE OF RATS TO MICROWAVE RADIATION HAVING INTENSITIES OF 5 TO 50 mW/cm<sup>2</sup>. (Ser.)

Dordevic, Z. (Inst. Aeronaut. Med., Zemun, Yugoslavia). *Vojnosanit. Pregl.* 32(1):51-53, 1975.

Experiments were performed on 480 male Wistar rats that were divided into two groups and exposed to: (1) 10 doses of MW radiation (5-50 mW/cm<sup>2</sup> for 2 hr/day) or (2) a single dose of 5-50 mW/cm<sup>2</sup> for 2 hr. The frequency of the MWs was 2400 MHz and the wavelength, 12 cm. Body weight and temperature were measured, and differential blood counts and ophthalmological examinations were performed before and after exposure of rats in group 1. These animals were then placed in a chamber under conditions simulating those found at an altitude of 11,000 m above sea level until they died. Rats in group 2 were sacrificed after exposure, histological examinations were performed on their tissues, and the contents of catecholamines were determined in their brains and hearts. The threshold dose which produced significant changes in the biological parameters measured was 10 mW/cm<sup>2</sup>. Exposure of rats to this dose for 10 days increased rectal and axillary temperatures and produced leukopenia accompanied by relative neutrophilia and lymphopenia. The extent of



these changes increased with increasing doses of radiation. No changes occurred in the number of erythrocytes or platelets or in hemoglobin levels in any of the experimental animals. All rats, including those repeatedly exposed to 5 mW/cm<sup>2</sup> or more of radiation, also had decreased resistance to acute hypoxia. The absolute lethal dose for restrained rats was 30 mW/cm<sup>2</sup>. Animals exposed to this dose developed motor excitation, clonic convulsions, and respiratory collapse and died within 2 hr. Immediately before death the rectal temperature increased to 44 C. Histological examinations performed on rats in group 2 demonstrated that death resulted from the thermal effect of MW radiation which caused thermoregulatory mechanisms to fail. Peripheral blood changes appeared to result from the stressor effect of MW radiation at intensities of 10 mW/cm<sup>2</sup> or higher. These changes were apparently caused by irritation of the hypothalamus, pituitary, and adrenals. No cataracts or other pathological changes were present in the eyes of any of the experimental animals. (No references)

0673 THE EFFECT OF UHF ELECTROMAGNETIC FIELDS ON THE VIABILITY OF PLEROCERCIDS OF *DIPHYLLOBOOTHRIUM LATUM*. (Rus.) Romanov, I. V. (S. M. Kirov Med. Inst., Gorky, USSR), M. Iu. Ulyanov, and Iu. V. Smirnov. *Med. Parazitol. (Mosk.)* 43(1): 108-109, 1974.

Plerocercoids of *Diphyllobothrium latum*, the fish tapeworm, were placed in petri dishes containing 10 ml physiological saline and were exposed to UHF radiation with a frequency of 39 MHz or 2189 MHz (field intensity of approximately 30-35 V/m) for 10 or 60 min and to radiation with a frequency of 2189 MHz and a field intensity of approximately 10 V/m for 10 or 60 min. Unexposed controls lived 2-3 days longer than plerocercoids exposed to the UHF fields. The survival time of irradiated plerocercoids decreased significantly with increasing exposure and depended on the frequency and wavelength of the radiation. To check the viability of irradiated plerocercoids, 6 irradiated with 2189 MHz for 60 min were fed to a dog. After 13 days the dog was autopsied and 2 immature tapeworms were found in the intestine: one was 30 cm long and the other, only 1.6 cm long. The latter specimen had an abnormal, degenerated strobila. (No references)

0674 CHANGES IN RAT TESTES CAUSED BY EXPOSURE TO A LOW FREQUENCY, PULSED ELECTROMAGNETIC FIELD. (Rus.) Ostrovskaya, I. S. (Kharkov Res. Inst. Ind. Hyg. Occup. Dis., USSR), L. N. Yashina, and G. I. Yevtushenko. *Vrach. Delo* (9):139-142, 1974.

Histological examinations and histochemical studies of ribo- and deoxyribo-nucleoprotein were performed on testes from 150 albino rats which had been exposed to a low frequency (7 kHz) pulsed EMF. The field intensity ranged from 0.4 to 72 kA/m, the duration of pulses was 130  $\mu$ sec, and pulses were spaced 10

sec apart. Rats were divided into two groups and were exposed: (1) for 3 hr/day over 10-15 days or (2) for 30 min/day over 1-6 months. Pronounced morphological changes occurred in the testes of rats exposed to a field intensity of 72 kA/m for 10 days. These changes consisted of interstitial edema, plethora, dystrophic changes in cells of the seminiferous tubules, decreases in the number of sperm cells, and dystrophy and necrosis of spermatozooids. Similar changes were observed in rats exposed to 24 kA/m, but the extent of these changes depended upon the duration of exposure. Decreases had occurred in the ribonucleoprotein content of the protoplasm in first order spermatocytes, especially during growth and division. Damage to forming spermatozooids and spermatozooids was more pronounced in the testes of rats in group 2. These cells were swollen and often fused to form 'sperm balls' in the lumina of the tubules. No spermatozooids were found in most tubules, and those that were present had undergone dystrophic changes. Sertoli cell function appeared to be relatively unimpaired. The cytoplasm of Sertoli cells contained lipid granules which are considered by some investigators to result from phagocytosis of lipids from residual bodies formed during reductive division. These changes were most pronounced in rats exposed for 6 months; the testes in these animals were about half the size of those in controls. In group 2, morphological changes were found in rats exposed to field intensities as low as 2.4 kA/m. These findings confirm that the testes of rats are highly sensitive to low frequency, pulsed EMR. (No references)

0675 EFFECT OF ATP AND GLUTAMIC ACID ON OXIDATIVE PHOSPHORYLATION AND NITROGEN METABOLISM IN THE BRAIN AND LIVER OF RATS EXPOSED TO A PULSED ELECTROMAGNETIC FIELD. (Ukr.) Mishchenko, L. I. (Kharkov Res. Inst. Ind. Hyg. Occup. Health, USSR) and F. A. Kolodub. *Ukr. Biokhim. Zh.* 47(4):528-531, 1975.

ATP (1 mg/100 g/day) and glutamic acid (5 mg/100 g/day) were injected s.c. into nonirradiated rats and rats which were simultaneously exposed 15 times, for 3 hr at each session, to a pulsed EMF (frequency 7 kHz, field intensity 72 kA/m). Controls received 0.2 ml/day of physiological saline. Irradiation of rats significantly decreased the P/O coefficient by reducing the rate at which inorganic phosphate was esterified (by 33% in the brain and by 22% in the liver). Injection of ATP in nonirradiated rats significantly decreased the rate of O<sub>2</sub> uptake (by 13% in the brain and by 9% in the liver) and significantly increased the rate at which inorganic phosphate was esterified in the liver (by 18%). This resulted in a significant increase in the P/O coefficient. However, administration of ATP to irradiated rats had no effect on O<sub>2</sub> uptake and phosphorylation in either the brain or liver. This may be due to changes produced by irradiation in the structure of the mitochondrial membranes. Injection of glutamic acid into irradiated rats increased the rate at which inorganic phosphates were esterified in the brain and liver to values characteristic for controls.



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No appreciable change occurred in oxidative processes. Irradiation significantly decreased the lactate content of the liver (by 32.2%), possibly by activating oxidative processes. In irradiated rats given ATP, lactate contents were decreased not only in the liver, but also in the brain (by 31%). No increase occurred in the creatine phosphate content of the brain in these rats. Irradiation significantly increased the content of ammonia in the brain (by 54%) and glutamine in the liver (by 32%); both of these values normalized after administration of ATP. Glutamic acid normalized the content of these metabolites in the brain and, to a lesser extent, in the liver. It is suggested that complete normalization of nitrogen metabolism in the liver might be prevented by its increased production of urea which has been shown to occur when animals are exposed to pulsed EMFs. (11 references)

- 0676 BEES EXPOSED TO HIGH VOLTAGES. (Ger.)  
Warnke, U. (Fachber. Biol. Univ. Saarbrücken,  
Germany) and R. Paul. *Umsch. Wiss. Tech.* 75(13):  
415-416, 1975.

Abnormal behavior was induced in bee colonies in Styropore boxes by exposing them to electrical fields produced by high voltage generators at 50 Hz. This behavior could be reproduced under certain (unspecified) meteorological conditions. The bees became very restless when placed in an alternating field at a maximum intensity of 11 kV<sub>eff</sub>/m. This can be attributed to the change in temperature. The bees also became very aggressive, not only toward outsiders, but even toward other bees in the colony and their own queen. Some of the bees that were attacked were stung to death. At lower field intensities (7 kV<sub>eff</sub>/m), only some of the brood were fed; the workers no longer stored honey and pollen, and cells which had been filled with honey were emptied. If colonies had been placed in the Styropore box only a few days before they were exposed to the electrical field, bees went out again after a few days. However, if the bees had lived in these boxes for some time before exposure, they cemented up all tears and holes, including the flight hole. Within 5 days, the flight hole was completely closed, acute oxygen deficiency set in, and the entire colony suffocated. The temperature in the hive was so high that the wax melted. (8 references)

- 0677 AUTORADIOGRAPHIC ANALYSIS OF PROTEIN SYNTHESIS AND MEASUREMENTS OF NUCLEAR VOLUME IN WISH CELL CULTURES IRRADIATED WITH 3 GHZ ELECTROMAGNETIC RADIATION. (E.) Szmigielski, S. (Inst. Aviat. Med., Warsaw, Poland) and M. Luczak. *Phys. Med. Biol.* 20(5):825-833, 1975.

The investigation aimed to evaluate the relationship between the amount of protein synthesis and nuclear volume in cells irradiated with MWs, and to determine the relation between time and inhibition and stimulation under these conditions. WISH cell cultures were irradiated 24 hr after passage with 3

GHz MWs for 30 min at intensities of 5 or 20 mW/cm<sup>2</sup>. After 1, 4, 12 and 24 hr of exposure the cells were incubated with 5 µCi/ml of <sup>3</sup>H-glycine and autoradiographs were made using stripping film. The incorporation of the amino acid was measured for four groups, 0-10, 10-20, 20-40, and above 40 grains per cell. Karyometric analysis of irradiated cell cultures was performed 1, 4, 8, 12, 24 and 48 hr after exposure. In cultures irradiated at an intensity of 20 mW/cm<sup>2</sup>, inhibition of protein synthesis with lowering of nuclear volume and enlargement of nucleoli was found one hr after irradiation. This was followed by increase in glycine incorporation 12 and 24 hr after irradiation with enlargement of nuclei. In cultures irradiated at an intensity of 5 mW/cm<sup>2</sup> stimulation of protein synthesis and enlargement of nuclei were seen 24 hr after irradiation. These results suggest that low intensity MWs stimulate metabolism of cells grown *in vitro*, although at higher intensities the phase of stimulation is preceded by a short period of inhibition in the culture viability. (26 references)

- 0678 MICROWAVE EFFECT ON RABBIT SUPERIOR CERVICAL GANGLION. (E.) Courtney, K. R. (Dep. Rehabil. Med., Sch. Med., Univ. Washington, Seattle), J. C. Lin, A. W. Guy, and C-K. Chou. *IEEE Trans. Microwave Theory Tech.* MTT-23(10):809-813, 1975.

An investigation was made to discover where precisely known doses of MW radiation would be applied to the nervous tissues of higher complexity, i.e., nervous tissue containing synaptic connections. The superior cervical ganglion of the rabbit was selected for excision and exposure to CW 2450 MHz fields within a temperature controlled waveguide environment. Absorbed power densities between 2 and 1000 W/kg failed to influence significantly transmission latencies of responses recorded from postganglionic fibers due to stimulation of either myelinated or unmyelinated fibers in the preganglionic trunk. (12 references)

- 0679 FOCUSED MICROWAVE RADIATION: A TECHNIQUE TO MINIMIZE POST MORTEM CHANGES OF CYCLIC NUCLEOTIDES, DOPA AND CHOLINE AND TO PRESERVE BRAIN MORPHOLOGY. (E.) Guidotti, A. (Lab. Preclin. Pharmacol., Natl. Inst. Ment. Health, Washington, D. C.), D. L. Cheney, M. Trabucchi, M. Doteuchi, C. Wang, and R. A. Hawkins. *Neuropharmacology* 13(12):1115-1122, 1974.

An inexpensive high power (2 kW) MW radiator was developed which can be focussed on the mouse or rat head. It inactivates the brain enzymes in 0.5-2.5 sec, depending on size of animal, and allows measurement of brain concentrations of cyclic AMP, cyclic GMP, choline, DOPA, and various glucose metabolites which undergo rapid metabolism during the post mortem processes. The microwave fixation technique offers the advantage that the brain can be sliced with a freezing microtome to allow microdissection of various brain nuclei for neurochemical studies. Irradiation of the rat head for 0.5 sec produced death of

the animal, but complete denaturation of the brain proteins was achieved after only 1 sec of MW exposure. When compared to the freeze-blowing technique the metabolite concentrations are similar as well as the oxydoreductive state of tissue. The new MW technique, by allowing for microdissection, therefore establishes an important precondition for microchemical studies related to brain function. (29 references)

0680 SOME AUTONOMIC REACTIONS IN RABBITS EXPOSED TO A UNIFORM MAGNETIC FIELD. (Rus.)

Klimovskaya, L. D. (No affil.) and N. P. Smirnova. *Kosm. Biol. Aviakosmicheskaya Med.* 9(3):18-22, 1975.

Exposure of rabbits to a uniform magnetic field (4500 Oe) for 3 hr significantly reduced the rate of respiration for 3 hr after exposure had ended. Arterial pressure decreased during exposure but normalized within 1 hr after exposure. Although the pulse did not change significantly, significant decreases were observed in some animals during exposure and for short periods thereafter. Before exposure to the magnetic field, injections of epinephrine (4 or 10  $\mu\text{g}/\text{kg}$  i.v.) produced dose-dependent bradycardia and increases in blood pressure, but the effects on respiration varied greatly. Cardiovascular response to 10  $\mu\text{g}/\text{kg}$  epinephrine was reduced when injections were performed 1-3 hr after exposure. Exposure to the magnetic field had no effect on cardiovascular changes produced by acetylcholine (20  $\mu\text{g}/\text{kg}$  i.v.) or by electrical stimulation of the reticular formation in the midbrain (100/sec stimuli from a square-wave generator for 30 sec). Exposure of rabbits to the magnetic field before or after they had been subjected to accelerations of 6 or 10 g did not decrease cardiovascular or respiratory compensation in the animals. (6 references)

0681 HEATING PATTERNS PRODUCED IN HUMANS BY 433.92 MHZ ROUND FIELD APPLICATOR AND 915 MHZ CONTACT APPLICATOR. (E.)

Lehmann, J. F. (Dep. Rehabil. Med., Univ. Washington Sch. Med., Seattle), B. J. DeLateur and J. B. Stonebridge. *Arch. Phys. Med. Rehabil.* 56(10):442-448, 1975.

Theoretically, 433.92 MHz MWs should selectively heat muscle more effectively than 915 MHz MWs, which is a frequency legal for diathermy use in the U.S. To test this, 20-45 yr old human volunteers were used to determine the temperature distribution produced by a 433.92 MHz round field applicator as compared to a 915 MHz contact applicator. The subjects were divided into 2 groups: those with  $\leq 1$  cm fat in the anterior thigh of the right leg and those with  $\geq 2$  cm fat. This portion of the thigh was scrubbed and temperature measuring probes were inserted up to a depth of 4-5 cm. All subjects were exposed to 433.92 MHz MWs at a power output of 55 W for 20 min. The difference between incident and reflected power was measured. At the end of 20 min exposure, the combined effect of continued heating with MWs and cooling by increased blood flow allowed the muscle temperatures to rise to therapeutic temperatures ( $\geq 40$

C). Four of the five subjects had their highest recorded temperature in the muscle, while one had the highest temperature at the skin surface or in subcutaneous tissue. The effective depth of heating was on the average 2.4 cm from the interface into the muscle at 433.92 MHz and 2.5 cm at 915 MHz. In subjects with  $\geq 2$  cm fat the peak temperatures also occurred in the superficial muscle and were cooled by increased blood flow. After 20 min the highest temperature was found in the subcutaneous fat which is only slightly cooled. When the cooled contact 915 MHz applicator was used, temperatures at the skin surface were much lower, but the highest temperature still occurred in the subcutaneous fat layer. As no significant differences were found in using 433.92 MHz vs 915 MHz radiation, there is no reason to legalize the 433.92 MHz frequency for diathermy use in the U.S. (12 references)

0682 ADRENOCORTICOTROPHIC ACTIVITY OF THE PITUITARY UNDER THE EFFECT OF A UHF FIELD.

(Rus.) Murashov, B. F. (D. I. Ulyanov Med. Inst., Kuibyshev, USSR), P. E. Krasnobaev, V. L. Goban, and V. A. Romanushko. *Gig. Tr. Prof. Zabol.* (3):36-38, 1975.

The ACTH activity of the blood was determined by Sayer's method in 82 men, aged 19 to 50 yr, who had worked with UHF generators for 6 months to 11 yr. Controls consisted of 23 clinically normal subjects. The ACTH activity was significantly higher in workers exposed to UHF radiation (28.5 mg/100 ml) than in controls (value not given), suggesting that the low intensity UHF fields used in industry increase pituitary function. A single exposure of Wistar rats to a UHF field (wave length 12.62 cm, power flux densities of 0.1, 1, or 10  $\text{mW}/\text{cm}^2$ ) significantly increased ACTH activities, whereas a single exposure of rats to high intensity (100  $\text{mW}/\text{cm}^2$ ) UHF radiation for 30 min had no effect on the ACTH activity of their blood. When rats were exposed to low intensity (1  $\text{mW}/\text{cm}^2$ ) UHF radiation for 30 min/day for a relatively short period (10-20 days), the ACTH activity increased, but the increase was not statistically significant. The ACTH activity tended to decrease in rats irradiated under the same conditions for 30 days. Pituitary stimulation occurred in both nonirradiated and irradiated rats (1  $\text{mW}/\text{cm}^2$  for 30 min/day for 30 days) when 0.12 mg/kg of epinephrine was injected i.p. This indicates that exposure to UHF radiation in the range studied does not impair the ability of the pituitary-adrenal system to respond to epinephrine. The reversible functional changes observed in these experiments are probably caused by disorders in processes regulating secretion of ACTH. (10 references)

0683 EXPERIMENTAL STUDY OF SOME PROBLEMS ABOUT THE BIOLOGICAL EFFECT OF WATER EXPOSED TO A UNIFORM MAGNETIC FIELD. (Rus.)

Stefanov, B. (Med. Acad., Varna, Bulgaria) and S. Solakova. *Gig. Sanit.* (8):70-72, 1975.

The body weight, rectal temperature, and blood were



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investigated in 3 groups of albino rats fed (1) ordinary drinking water, (2) water exposed to a uniform magnetic field (induction 0.1 tesla), or (3) water exposed to a uniform magnetic field (induction 0.6 tesla). Rats in groups 2 and 3 were given 2.5 ml/day of 'magnetic' water p.o. through a stomach tube for 45 days and received the rest of their water in petri dishes. The most pronounced biological effects were observed in rats in group 2. After 45 days, significant decreases had occurred in the absolute weight gain; total serum protein;  $\text{Na}^+$ , and  $\text{K}^+$ ; and rectal temperature. The number of reticulocytes in the blood increased significantly. There was a tendency for total blood cholesterol concentrations to decrease. None of these changes exceeded normal limits. (No references)

0684 DESTRUCTION OF SALMONELLAE ON POULTRY MEAT WITH LYSOZYME, EDTA, X-RAY, MICROWAVE AND CHLORINE. (E.) Teotia, J. S. (Dep. Anim. Sci., Colorado State Univ., Fort Collins) and B. F. Miller. *Poult. Sci.* 54(5):1388-1394, 1975.

Experiments were conducted to study the destruction of *S. senftenberg* 775W and *S. typhimurium* on poultry meat with lysozyme, EDTA, x-rays, MWs, and chlorine. A frozen stock culture of the microorganisms was incubated until it reached the stationary growth phase. It was then diluted in 0.1% sterile peptone water to a concentration of  $5 \times 10^5$  to  $8 \times 10^5$  viable cells/ml. Small white turkey hen carcasses and medium size drumsticks were placed in bags and covered with 500 ml aliquots of the contaminating fluid. The bag was shaken for 2 min and the fluid was poured off. The carcass was held in the closed bag at room temperature for 60 min before experimental treatment. Each carcass was aseptically transferred into a glass pan and covered with sterile Saran Wrap. They were irradiated in a MW oven for 1-10 min each, removed from the pan, and examined for any change in physical appearance. The test organism and other bacteria were destroyed in 120 sec on drumsticks and in 600 sec on broiler carcasses with MW irradiation. MW treatment produced partially cooked meat. If this cooking had no effect on shelf life, flavor, and acceptability by customers, it could be the quickest and cheapest means of destroying salmonella on poultry meat. (13 references)

0685 EXPERIENCE WITH MAGNETOTHERAPY FOR PAINFUL NEUROMAS IN STUMPS OF THE EXTREMITIES. (Rus.) Kucherenko, A. E. (Vinnitsa Med. Inst., USSR) and V. I. Shevchuk. *Vrach. Delo* (7):124-125, 1975.

Magnetotherapy was used to treat 42 World War II veterans, aged 48-75 yr, who had undergone amputations for gunshot wounds and fractures 29-32 yr previously. All of the patients had painful neuromas in the stumps of the extremities and severe phantom pain syndrome. The stump of the upper or lower extremity was placed between the poles of an electromagnet with an alternating magnetic field of 200-400 Oe for 15 min/day over a 20 day period. Pain was alleviated after the first session and edema after

3-4 days. Edema and inflammation disappeared completely after 10-11 days, sleep normalized, and neurotic reactions disappeared. To improve the results of therapy, magnetotherapy was continued even after the pain disappeared. Pain was completely alleviated in 37 patients. In 3 cases, there was no pain at rest, and slight pain was felt only when the neuroma was palpated. Two patients had no pain at rest, but a spastic sensation persisted in the phantom limb. Magnetotherapy proved superior to all of the methods tested so far. These include electro-sleep, ultrasound, diodynamic currents, and electrophoresis combined with analgesics. The results of special tests indicate that magnetotherapy has an inhibitory effect on the CNS, a spasmolytic action on peripheral blood vessels, and analgesic and antiedemic actions. (No references)

0686 EFFECT OF A UNIFORM MAGNETIC FIELD ON ABSORPTION SPECTRA OF PROTEINS FROM ASCITES TUMOR S-37 AND HEMOGLOBIN FROM NORMAL AND TUMOR-BEARING ANIMALS IN VITRO. (Rus.) Aristarkhov, V. M. (Inst. Chem. Phys., Moscow, USSR), L. A. Piruzian and V. P. Tsybyshev. *Izv. Akad. Nauk SSSR [Biol.]* (6):917-920, 1974.

The effect of a uniform magnetic field (5000 Oe for 17 or 18 hr) on absorption spectra was studied in dilute solutions of ascites fluid proteins from animals [species unspecified] with ascites sarcoma S-37 in different stages of development and in dilute solutions of hemoglobin from normal animals and animals with ascites sarcoma S-37. Spectra were recorded 3 hr after removal of the solutions from the magnetic field. After exposure to the magnetic field, absorption spectra of ascites fluid protein from 7 day old sarcoma S-37 showed an increase in the intensity of absorption at 280 nm due to increased aggregation of protein molecules. When the spectrum of a nonexposed control solution was subtracted, 2 peaks appeared at 275 and 234 nm. The peak at 275 nm is probably caused by a tyrosyl group. Similar results were obtained when a technique was used which eliminated light scattering. Further investigations on protein from ascites sarcoma S-37 in different stages of development showed that exposure to the magnetic field generally, but not always, increased the intensity of absorption. These different results are attributed to differences in the state of ascites fluid proteins during tumor development. Exposure of a hemoglobin solution from normal animals to a constant magnetic field decreased the intensity of absorption and shifted the main peak at 413 nm toward a shorter wavelength. This indicates that the magnetic field causes profound structural changes in the hemoglobin molecule. In contrast, the magnetic field decreased the intensity of absorption only slightly in hemoglobin solutions from animals with 7 day old ascites sarcoma S-37, but the peak was still shifted. If the absorption spectrum for hemoglobin from tumor-bearing animals was plotted relative to that for hemoglobin from normal controls, similar results were obtained. No shift in the peak was observed when the same method was used to plot the spectrum for hemoglobin after exposure to the



magnetic field. These results indicate that the magnetic field has a normalizing effect, i.e. the field eliminates those structural changes in the hemoglobin molecule which result from tumor development. (8 references)

- 0687 A SUMMARY OF THE ERMAC WORK SESSION ON NERVOUS SYSTEM AND BEHAVIORAL EFFECTS OF NON-IONIZING ELECTROMAGNETIC RADIATIONS. (E.) Galloway, D. (BRH, FDA, PHS, Washington, D.C.), S. M. Bawin, J. Frazer, W. Stavinocha, A. Guy, R. Lovely, D. Hawkins, J. Schrot, J. R. Thomas, D. R. Justesen, E. L. Hunt, A. Frey, R. Seaman, and M. DeSantis. *J. Microwave Power* 10(2):127-140, 1975.

On October 31 and November 1, 1974, an Electromagnetic Radiation Management Advisory Council (ERMAC) work session took place in Washington, D.C., to review research and progress pertaining to possible nervous system and behavioral effects of NIR and to assess the biological effects of these radiations. The participants described their current research efforts, after which a summary and set of recommendations were drawn up. It was noted that a large amount of material is emerging with commonality, especially with regard to biochemical, endocrine, and neuroendocrine effects. There remains a need to build up a greater base of information without precluding new or innovative approaches. Liaison and communication between laboratories and agencies should also be improved. In the neural/behavioral field, indications of nervous system and behavioral effects warrant further investigation, particularly in terms of specific exposure conditions and health conditions. Difficulties in determining doses and distribution of absorbed energy remain and the importance of characterizing power density and absorbed energy in a uniform manner was emphasized. Measurement guidelines should be published. Discrepancies between studies in which performance effects were observed only during irradiation and those in which they were observed following exposure were noted and a hypothesis for a possible mechanism was suggested which could account for this. The difference between pulsed and CW radiation effects should be studied with associated neurochemical and mechanism studies. The use of RF as a tool for understanding brain function was noted. Areas requiring more emphasis included: chronic exposure; separation of E and H fields; CW vs PW effects, parallel efforts to investigate mechanisms; more work at the biophysical, membrane, and neurochemical levels; and uniformity of measurement to allow extrapolation between animals and man. The levels of funding for this research are inadequate and multi-year funding was particularly stressed. (No references)

- 0688 FLAVOR AND CHEMICAL CHARACTERISTICS OF CONVENTIONALLY AND MICROWAVE REHEATED PORK. (E.) Penner, K. K. (Dep. Foods Nutr., Kansas State Univ., Manhattan) and J. A. Bowers. *J. Food Sci.* 38 (1973):553-555, 1974.

Flavor and aroma of MW and conventionally reheated and

stored pork were compared with that of fresh conventionally cooked pork, and the relation of flavor and aroma to various chemical characteristics of the heat treated meat was studied. Most aroma and flavor components of freshly cooked and reheated pork were similar. No significant differences were found between freshly cooked and MW reheated pork, but some differences were noted between conventionally reheated muscle and that of the other treatments. MW reheated muscle is more like freshly cooked muscle than is conventionally reheated muscle. Total ninhydrin-reactive compounds and amount of protein in various tissue extracts were not affected significantly by the heating treatments. (20 references)

- 0689 EXPERIMENTAL MODELS FOR THE EVALUATION OF MICROWAVE BIOLOGICAL EFFECTS. (E.) Czernski, P. (Dep. Hum. Genet., Natl. Res. Inst. Mother Child, Warsaw, Poland). *Proc. IEEE* 63(11):1540-1544, 1975.

Biological organisms are self regulating systems equipped with interdependent homeostatic mechanisms. Absorption of radiant energy creates a disturbance which activates these mechanisms. Biological effects resulting from exposure should be considered as a chain of events initiated by the primary interaction of radiation with living matter and may be classified as early (immediate) direct effects, early (immediate) indirect (secondary) effects, or late (delayed) effects. This approach should serve in experimental design and interpretation of results obtained in MW experimentation. The term primary interaction should refer to the mechanisms of radiation energy absorption and direct interference with biophysical, biochemical, and bioelectrical mechanisms or phenomena in the living system. The present knowledge of biophysics of complex living systems is insufficient to predict the whole range of modes of the primary interaction of MWs with such systems. Assessing the biological significance of the phenomena produced is also difficult. Empirical observations should be included in the knowledge forming the basis for further experimental approaches and used for verification of the validity of theoretical predictions. The most investigated primary interaction of MWs with living systems is the transformation of absorbed energy into increased kinetic energy of the absorbing molecules. Its physiological consequences are insufficiently taken into account in experimental design. The internal distribution of fields within the irradiated object is nonuniform and is a function of frequency, exposure conditions, tissue geometry and dielectric properties. An increase in temperature changes metabolic rate and magnitude of blood flow (early direct biologic effects) and these changes influence metabolism and transport of metabolites. These local changes may influence the function of the whole organism (secondary early biological effects). It becomes obvious that research on MW biological effects is a highly interdisciplinary domain which requires a team consisting of a physiologist, cytologist, biochemist, biophysicist, and electronics engineer. In future research, thermal balance characteristics of animals exposed to MWs should be studied; physiological and pharmacological methods should be used to discriminate between early immediate and secondary biological effects; the possibilities for developing biological MW dosimetric indices should be examined;

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and effects on growth and development should be urgently investigated under carefully controlled conditions. (55 references)

### 0690 EVALUATION OF POSSIBLE MICROWAVE-INDUCED LENS CHANGES IN THE UNITED STATES AIR FORCE. (E.)

Shacklett, D. E. (U.S. Air Force Sch. Aerosp. Med., Brooks Air Force Base, Tex.), T. J. Tredici, and D. L. Epstein. *Aviat., Space, Environ. Med.* 46(11):1403-1406, 1975.

A Joint Service Ad Hoc Committee on Microwave Ocular Effects was formed to research MW effects in terms of lens changes using an epidemiologic approach. If significant ocular effects occurred from exposure to MWs, a difference between control and study groups could be statistically determined. The presence or absence of effects was recorded qualitatively using three diagnostic signs: opacities, vacuoles, and posterior subcapsular iridescence. Subjects (477) and age matched controls (340) were examined at 8 different Air Force bases over a 3 yr period. The subjects had known histories of having worked around MW generating equipment. Controls had no known MW exposure. Examination included a detailed work history, past medical history, and family history. The distant visual acuity was measured for each eye individually and pupils were dilated. In a double-blind study the subjects were examined for the 3 lenticular criteria and given an external ocular examination and direct ophthalmoscopic fundus examination. The groups were broken into age decades and compared. No significant differences were seen between the 2 groups: 60% of the controls and 56% of the study subjects had lenticular opacities; 41% of each group had vacuoles; and 62% of the controls and 60% of the study subjects had posterior subcapsular iridescence. An expected increased incidence of lens changes with age was seen. This study does not support the contention that MW exposure causes human cataracts at levels permitted by U.S. safety standards. (18 references)

### 0691 ELECTROMAGNETIC FIELD EFFECTS IN NERVE TISSUE. (E.)

Sandler, S. S. (Northeastern Univ., Boston, Mass.), G. S. Smith, and E. N. Albert. *Aviat., Space, Environ. Med.* 46(11):1414-1417, 1975.

An attempt was made to correlate morphological alterations in nerve tissue from the bullfrog with specific local electric fields in the tissue. A train of high intensity, short duration pulses was used to produce a high electric field intensity with negligible thermal heating. The peak electric field was  $1.3 \times 10^5$  V/m with a pulse repetition rate of 250 Hz. The nerve tissue of freshly dissected sections of the spinal cord and brainstem of bullfrogs was irradiated and the large motor neurons were used for histological study. The tissue was fixed, cut, and stained with thionin or hematoxylin. No significant histological differences were seen between control and exposed tissue, suggesting that previous findings may have resulted from appreciable amounts of thermal heating. (7 references)

### 0692 MICROWAVES CHALLENGE TODAY'S HEAT PROCESSING. (E.)

Schiffmann, R. F. (Bedrosian Assoc., Alpine, N.J.). *Food Eng.* 47(11):72-76, 1975.

Industrial MW heating is becoming a more important food processing tool due to economic and/or product quality benefits. Foods are processed faster, cheaper, and with less labor. Increased production, increased yield, and reductions in processing time pay for the initial investment. MW tempering of meat shortens tempering time, reduces drip loss, and improves sanitation. The MW doughnut proofer heats dough uniformly to 45.5 C in just 4 min from cutter to fryer. It provides speed and better control of production and product quality. The MW fryer yields a product which never before existed: a coreless doughnut which is larger and less chewy. A MW dryer is used to produce uniformly dried pasta at lower capital costs and process times, with lower requirements for space. Internal heating by MWs drives the water to the surface very efficiently to avoid hardening. To thaw fish, new thawing tunnels use refrigerated air (-30 C) in the MW system. The production of kw-hr of MW power is more costly when thawing than when tempering, but not any higher than present methods. Some potential commercial uses of MW include freeze drying and/or vacuum drying. Though still being researched, the process is presently used commercially in Europe to make natural color extracts and to dry tea leaves. MW baking hopes to make use of domestic soft wheat flour as a partial replacement for imported hard wheat. Continued use of MWs in the puffing, drying, and blanching of foods awaits further investigations. (No references)

### 0693 MEASURE OF ENZYMIC ACTIVITY COINCIDENT WITH 2450 MHz MICROWAVE EXPOSURE. (E.)

Ward, T. R. (Exp. Biol. Lab., Natl. Environ. Res. Cent., EPA, Research Triangle Park, N.C.), J. W. Allis, and J. A. Elder. *J. Microwave Power* 10(3):315-320, 1975.

A dual beam Cary 15 spectrophotometer was fitted with a waveguide tuner and applicator so that a sample could be irradiated at 2450 MHz while being spectrophotometrically compared to an unirradiated reference solution. The CW beam was perpendicular to the light path and irradiated the sample through the top of the open cuvette. Enzymatic activities were determined at 25 C. Temperatures in both reference and sample solutions were measured continuously with microthermocouples, as enzymatic activity is temperature sensitive. To maintain 25 C during irradiation the sample was regulated at 19.8 C without radiation. Total irradiation time was about 5 min. Human and Torula yeast glucose 6-phosphate dehydrogenase were assayed for enzymatic activity by following the change in absorbance at 340 nm. Adenylate kinase from rat liver mitochondria and rabbit muscle were determined at 340 nm by the method of Schnaitman and Greenawalt. NADPH cytochrome c reductase was assayed at 550 nm. No differences were seen in specific activities of unirradiated and MW irradiated preparations ( $p \leq 0.05$ ). An absorbed dose rate of  $42 \pm 4$  W/kg was calculated from temperature differences before and during irradiation. These results are relevant to the use of a 2450 MHz MW blood warmer to raise the temperature of refrigerated bank blood



to body temperature prior to transfusion. The lack of a difference between control and sample NADPH cytochrome c reductase, which is membrane bound to the endoplasmic reticulum, is important in regard to the hypothesis that MW interactions can occur with biologic membranes. If membrane interaction does occur, it is not detectable as a change in enzymatic activity. (40 references)

- 0694 OXYGEN CONSUMPTION AND RESPIRATORY QUOTIENT IN FIVE ANIMAL POPULATIONS NATURALLY EXPOSED TO SANGUINE ELECTROMAGNETIC FIELDS. (E.) Greenberg, B. (Dep. Biol. Sci., Univ. Illinois, Chicago Circle). *Res. Rep.*, Contract No. N00039-73-0030, 16p, 1975.

A study was made to determine if or how ELF EM fields have biological effects. Specimens taken in September from the Sanguine experimental antennae in Wisconsin were tested. At this time mating and reproduction are over and day length is diminished. The animals tested included the wood louse, earthworm, redworm, slug, and redbacked salamander. These animals undergo a seasonal change in metabolic rate related to reproduction and general activity cycles so it was of interest to determine whether the fall populations responded differently to Sanguine EMFs because of their different physiologic states. Exposed and control animals, grouped for uniformity of size, were tested simultaneously. Oxygen consumption was measured in a closed manometric system. The electric and magnetic fields were measured at each collecting site. No significant difference was found in  $O_2$  consumption or respiratory quotient between test and control groups of fall animals. As all the species collected have limited mobility it is reasonable to assume that they are the third or later generation of animals that have been exposed to Sanguine-generated fields for 5 years. After 5 yr of Sanguine operation, metabolic rate, behavior, habitat selection and external features are not altered. (14 references)

- 0695 OVICIDAL LEVELS OF 2.45 GHz ELECTROMAGNETIC ENERGY FOR THE SOUTHERN CORN ROOTWORM. (E.) Fanslow, G. E. (Dep. Electr. Eng., Eng. Res. Inst., Iowa State Univ., Ames), J. J. Tollefson and J. C. Owens. *J. Microwave Power* 10(3):321-325, 1975.

To use EM energy as a nonpulluting means of controlling insects, it is necessary to determine the energy level required to produce a specific effect on a given insect. This study describes the determination of the threshold energy levels required to produce an ovicidal effect on the southern corn rootworm. The eggs of southern corn rootworm were subjected to EM energy at 2.45 GHz in slotted waveguide applicators. The effect of the EM energy was determined by comparing the average number of hatched eggs/treatment with the average number of hatched eggs/control. By comparing treatments with controls, the effect of EM energy can be separated

from normal egg mortality. IR measurements of temperature changes were made with a scanning system. The temperature changes found were very large, suggesting that the ovicidal mechanism is thermal. The most effective MW treatment occurs when a high power is applied for a short time. When a low MW power is applied for a longer time, the sample has time to cool, and it takes a larger amount of power to produce the ovicidal effect. (2 references)

- 0696 A THEORETICAL INVESTIGATION OF MICROWAVE IRRADIATION OF SEEDS IN SOIL. (E.) Olsen, R. G. (Dep. Electr. Eng., Washington State Univ., Pullman). *J. Microwave Power* 10(3):281-286, 1975.

Seeds in soil are exposed to MW radiation in an attempt to prevent germination. MW energy absorbed by the seed and soil is converted into heat resulting in lethal temperature rises. The larger the temperature rise, the larger the probability of lethal effects is. The seed can be heated to a significantly higher temperature than its soil environment and this can lead to a saving in the energy necessary to produce germination control. The amount of energy absorbed by seeds irradiated from above is not only a function of the dielectric field intensity and the exposure time, but also depends upon the reflection of the radiation from the surface and the geometry of the seed. Maximum power absorption occurs from frequencies in the range of 1 GHz for seeds buried at 2.5 cm. For seeds closer to the surface, higher frequencies will result in greater power absorption. For seeds buried more deeply, a lower frequency is desirable. The temperature rise of the seed is a function of the power dissipated in the seed, the duration of irradiation, and the heat capacity and mass of the seed. The soil type is an important factor in determining the effect of the exposure. For seeds buried in a mineral soil, the required energy density for germination control is in excess of 800 J/cm. The greater the thermal conductivity of the soil, the faster the decay in soil temperature is. (17 references)

- 0697 CONDITIONS OF STRONGEST ELECTROMAGNETIC POWER DEPOSITION IN MAN AND ANIMALS. (E.) Gandhi, O. P. (Dep. Electr. Eng., Univ. Utah, Salt Lake City). *IEEE Trans. Microwave Theory Tech.* MTT-23(12):1021-1029, 1975.

The strongest whole body absorption for biological bodies was found for EMFs polarized with the electric field along the long dimensions of the bodies. The major length is approximately 0.4 times the wavelength of radiation for bodies in free space. EM power absorption was measured for bodies of fixed size at various frequencies using a parallel-plate waveguide as a transmission medium of plane waves. Bodies scaled down in all dimensions result in peak absorption frequencies scaled up by the same factor and vice versa. Experiments with biological phantom figurines show a high power deposition in the neck region. Initial experiments with anesthetized and



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dead rats have shown a higher power deposition in the neck region than in the core of the animals. The frequencies of maximum absorption for adult humans is projected to be on the order of 65-75 MHz for free space conditions and about half as much in the presence of ground effects. (12 references)

- 0698 MUTAGENESIS BY RADIOWAVES IN ANTIRRHINUM MAJUS L. (E.) Harte, C. (Inst. Dev. Physiol., Univ. Cologne, West Germany). *Mutat. Res.* 29(1):71-75, 1975.

The pollen of *Antirrhinum majus* L. Sippe 50 was irradiated ( $\lambda = 1.5$  m; field strength = 1.5 V/m) for 4, 12 and 43 3/4 hr to test the mutagenic effect in the progenies. The irradiated pollen was crossed onto styles of emasculated flowers of plants in the greenhouse. The only difference between experimental pollen and the controls was the exposure to radiowaves. The frequency of progenies with a high percentage of empty seeds shows a correlation with the duration of the pollen treatment. Abnormalities were only counted as mutations when several seedlings of the same progeny showed the same character. The mutagenic effect was confirmed by the increase in embryonic lethality after selfing the  $M_1$  plants and the increase in relative frequency of segregating progenies with seedling anomalies. (9 references)

- 0699 THE DISTRIBUTION OF HEATING POTENTIAL INSIDE LOSSY SPHERES. (E.) Kritikos, H. N. (Dep. Bioeng., Moore Sch. Electr. Eng., Univ. Pennsylvania, Philadelphia) and H. P. Schwan. *IEEE Trans. Biomed. Eng.* BME-22(6):457-463, 1975.

One mechanism which contributes to the effects of EMFs on biological tissues is the process by which the heating potential is distributed inside the test objects. A nonuniform distribution implies the possibility of nonuniform temperature rise or the creation of hot spots. This study was designed to establish the conditions under which the heating potential peaks inside the test object and to determine the exact size and shape of these potential hot spots. Biological tissues are lossy dielectrics providing Joules heat when subject to EMFs. For this study, the dielectric properties of brain tissue in a homogenous sphere was chosen. In no case was the heating found to be uniformly distributed throughout the sphere. The type of nonuniformity was dependent on the radius of the sphere and frequency of the radiation. Two regions could be distinguished: one where heating takes place primarily at the front surface and a second where maximum heating takes place inside the sphere. The magnitude of the maximum heating potential was substantially different from values calculated by traditional methods, with maximum discrepancy (larger by a factor of 10) taking place in the region where hot spots occur. Hot spots occur only for small spheres and are therefore pertinent to heads

of small animals and infants. Only the heating potential was calculated; the resulting temperature rise is reduced by heat diffusion and heat convection due to blood flow. (7 references)

- 0700 CONFORMATION CHANGES IN rRNA INDUCED BY ELECTRIC IMPULSES. (E.) Revzin, A. (Max Planck Inst. Biophys. Chem., D-34 Göttingen, West Germany) and E. Neumann. *Biophys. Chem.* 2(2):144-150, 1974.

Electric impulse experiments were performed with a high power pulse generator equipped with a fast spectrophotometric detection system and polarization optics. The light intensity emerging through crossed polarizers is increased in the presence of the field while the intensity emerging through parallel polarizers is decreased. The time course of changes in UV absorbance and electric dichroism can be resolved into contributions from orientational and conformational changes. Results of experiments show a field induced effect and not an artifact form, e.g., cell distortion. The results of a typical electric dichroism experiment show that the fast changes when the rectangular pulse starts are due to (partial) rotation of double helical arms into the field direction. The slower part (relaxation times in the msec and  $\mu$ sec range) is shown to be due to changes in orientation of the entire rRNA molecule, concomitant with electric induced helix coil transitions of oligomeric base paired regions. The study indicates that such electro-optical studies may be complicated by conformational changes which occur in addition to orientation, especially for long impulses of high field intensity in solutions of low ionic strength. Conversely, possible orientation of molecules should be considered when analyzing optical changes in temperature jump experiments, since a large electric field is present as the capacitor is discharged during the jump. (33 references)

- 0701 DORSAL COLUMN STIMULATION. ITS EFFECT ON THE SOMATOSENSORY EVOKED RESPONSE. (E.) Blair, R. D. G. (Div. Neurol. Neurosurg., Toronto Western Hosp., Ontario, Canada), R. G. Lee, and G. Vanderlinden. *Arch. Neurol.* 32(12):826-829, 1975.

The physiological mechanisms by which dorsal column stimulation (DCS) relieves pain are not known. The effects of varying frequency, duration, and intensity of DCS in the individual components of the somatosensory evoked response (SER) are investigated. Six patients had been selected to receive implantation of a dorsal column stimulator to relieve chronic pain. The SER obtained by stimulating the tibial nerve at the ankle consisted of a series of positive and negative deflections beginning approximately 30 msec after the stimulus and lasting for more than 400 msec. Four subjects showed well defined responses of this type. During DCS there was a consistent reduction in amplitude of the late components of the SER. When the intensity of DCS was maintained at levels adequate to relieve pain, little change in the early components of the SER occurred during the first 100 msec. With higher voltage

levels of DCS, there was some suppression of all components of the response. Most patients reported best relief with DCS at frequencies around 100 Hz. The relief lasted several hours after a period of DCS. (11 references)

- 0702 MICROWAVE DRYING OF MICROORGANISMS: I. INFLUENCE OF THE MICROWAVE ENERGY AND OF THE SAMPLE THICKNESS ON THE DRYING OF YEAST. (E.) Gomes, A. M. P. (Dep. Chem. Eng., Sch. Eng. Mauá, Sao Paulo, Brazil), G. P. Leonhardt, M. Torloni, and W. Borzani. *J. Microwave Power* 10(3):265-270, 1975.

The study was made to ascertain whether MW heating could be used to dry yeast cells. A Microvac-2000, 2450 MHz MW oven, with an input power varying from 1.2 to 4.2 kW, was used in the experiments. Commercial pressed yeast in 500 g tablets was used in the drying tests. The moisture content of the pressed yeast was determined by drying 1.5 g of the sample in a conventional oven at 100-105 C for 5 hr. Drying time needed to achieve a final moisture content of 0.05 g of water/g of dry yeast and drying rate during constant rate period are provided. There was a good linear correlation between the power input and the drying rate calculated during the constant rate period. Sample thickness on the drying rate indicated that for a sample larger than 2.0 cm there is no significant variation of the constant drying rate. The results indicate a real possibility of using MW energy for drying single cell protein. (3 references)

- 0703 EVIDENCE FOR COOPERATIVE MECHANISMS IN THE SUSCEPTIBILITY OF CEREBRAL TISSUE TO ENVIRONMENTAL AND INTRINSIC ELECTRIC FIELDS. (E.) Adey, W. R. (No affil.). *Functional Linkage in Biomolecular Systems*, ed. F. O. Schmitt, D. M. Schneider, and D. M. Crothers (New York: Raven Press, 1975), pp. 325-342.

Information processing in brain tissue no longer is considered to involve only the nerve cells. There are strong physiological interactions between nervous and surrounding neuroglial cells. Surface regions may have other quite special functions in the detection and transduction of weak chemical and electrical events at the membrane surface. The characteristic phenomenon of overlapping dendritic fields in the palisades of cells that characterize all vertebrate cerebral ganglia may be associated with the concurrent development of a rhythmic electric wave process. This dendritic organization appears to constitute a specific arrangement in cerebral tissue. The possibility that brain tissue may be sensitive to field potentials in the environment of the neuron, including the intrinsic fields of the EEG, is discussed. Experiments involving monkeys are described which involve the effects of low level, low frequency electric fields on EEG and behavior. There was a decided trend to shorter interresponse times in the presence of the fields. To add to the evidence that membrane surface might transduce weak extracellular fields as a step in the excitation process, the effects of VHF electromagnetic fields, amplitude modulated at EEG frequencies, was studied. Unequivocal interactions have been demonstrated between the brain

tissue of mammals and birds and a variety of electric and EM fields. Behavioral effects from these studies occur with very low tissue electric gradients. Calcium ion appears to have an essential role in these interactions, and evidence points to a functional role for intrinsic electric gradients. (65 references)

- 0704 NONIONIZING RADIATION. (E.) Sliney, D. H. (No affil.) and D. L. Conover. *Industrial Environmental Health; The Worker and the Community*, ed. L. V. Cralley and P. R. Atkins (New York: Academic Press, 1975), pp. 157-177.

A review of the standards concerning physiologic effects of NIR, with an emphasis on new exposure criteria, is given. Mention is made of national consensus standards and federal rules which are near publication for several types of NIR, including lasers and MW exposure. The ANSI C95.1 standard was modified to include the specification of the TLVs in the equivalent free space electric field strength (200 V/m) and the magnetic field strength (0.5 A/m) for CW fields and in electric field strength squared (40,000 V<sup>2</sup>/m<sup>2</sup>) for modulated fields. This revision was primarily the result of a growing realization that separate electric and magnetic field strength measurements were mandatory for meaningful and accurate characterization of RF fields below approximately 300 MHz. (63 references)

- 0705 FREQUENCY AND ORIENTATION EFFECTS ON WHOLE ANIMAL ABSORPTION OF ELECTROMAGNETIC WAVES. (E.) Gandhi, O. P. (Dep. Electr. Eng., Univ. Utah, Salt Lake City). *IEEE Trans. Biomed. Eng.* BME-22(6): 536-542, 1975.

Studies were carried out to determine whether the total power absorbed in a whole animal body varies with frequency, what the frequency regions of most absorption for various polarizations are, what percentage of incident power is absorbed at such frequencies, and whether extrapolations to humans are possible. Using a parallel plate waveguide with a 6.35 x 15.9 cm<sup>2</sup> cross section, RF absorption of 96, 158, 261, and 390 g anesthetized Wistar rats was measured. The animals were placed on a styrofoam sheet to separate them from the waveguide plates as observed characteristics were independent of placement as long as the bodies were 2-3 mm from the plates. It was found that there is a definite frequency region of peak absorption and the frequency for maximum absorption reduces as  $W^{-1/3}$  with weight  $W$  of the animals. For frequencies below resonance, the power absorbed varies as  $f^{4.75}$ . At the absorption peak, the power absorbed varies as  $W^{2/3}$ , which is essentially an absorption cross section proportional to the shadow cross section of the animal. Above resonance, absorption reduces monotonically with increasing frequency. The effect of the tail on whole body absorption was minimal. The RF power deposition varied significantly with orientation and frequency, with the strongest absorption for waves polarized along the long dimension of the body at frequencies such that the major length is approximately  $\lambda/4$  wavelength of radiation in the presence of ground caused image. The highest whole body absorption for humans is predicted to be 40-50 MHz by extrapolation. (6 references)



CURRENT LITERATURE

- 0706 INDUSTRIAL AND SCIENTIFIC APPLICATIONS OF DOPPLER RADAR. (E.) Whetton, C. P. (Br. Rail Board, London, England). *Microwave J.* 18(11): 39-42, 1975.

The principal advantages of Doppler radar over other methods of speed measurement are the lack of any need of physical contact with the system and the ability of MWs to be directed into areas which are normally inaccessible. The MW hardware is usually very simple, ranging from single cavity devices to arrangements in which the oscillator power is transferred to the mixer by a coupler and a circulator is used to allow single antenna working. A physiological application of Doppler radar is its use to monitor the respiration rate of humans and animals. The radar is directed at the subject's chest and respiration rate is inferred from the periodic changes in Doppler shift frequency which occur as the chest wall moves. It is a great advantage that the radar needs no contact with the patient. The device causes no discomfort and, at 2.5 mW, presents no biological hazard. The same principle is used to form a respiration monitor in a polygraph system. (21 references)

- 0707 CLINICAL APPLICATION OF EM METHOD ON THE CENTRAL AND PERIPHERAL ARTERIES. (Jap.) Wanibuchi, Y. (Mitsui Mem. Hosp., Japan), H. Iijima, F. Sano, M. Nakanishi, A. Nishimura, and S. Okino. *Kokyu To Junkan* 22(7-8):605-610, 1974.

The application of the electromagnetic method to measure human blood flow is presented with examples of measurements in large arteries. The flow measurement results for the aorta and pulmonary artery in both pre- and post-operations of ASD indicated the same blood flow volume in the aorta and pulmonary artery upon the disappearance of the left-right shunt. The arterial blood flow wave of a patient with aortic insufficiency indicated that the disappearance of the back current of blood could be seen after an operation to install an artificial valve. The quantitative diagnosis of heart rate and back current could be determined from the pulmonary artery blood flow wave for a patient with Fallot's tetralogy. The EM blood flow measurement can be used for the selection of an effective drug for enlarging peripheral arteries. The blood inflow wave measured at the upper arm of a patient indicated an increase in the blood inflow rate from 40 ml/min to 262 ml/min after arterial injection of 5 ml Priscoline. The EM measurement of blood flow was limited to its use in animal experiments until a few years ago; however, the technique has been applied in human surgical cases, and the comparable accuracy of the blood flow measurement obtainable in animal experiments is possible in human applications. (17 references)

- 0708 ECOLOGICAL INFLUENCE OF ELECTRIC FIELDS. (E.) Bankoske, J. W. (Westinghouse Electr. Corp., East Pittsburgh, Pa.) and G. McKee. *Res. Rep.* No. EPRI 129, 20p, 1975.

This project was initiated to study effects of electric fields on plants, animals, and soils in the vicinity of

high voltage transmission lines. It was necessary to determine the nature of electric fields in the vicinity of actual transmission lines, including the calculation of the magnitude of fields at ground level, several meters above ground, and the lateral profile of the gradients in a direction perpendicular to transmission lines. The maximum gradients that were calculated were used to set reasonable limits on the fields. The electric field intensity can be minimized by using a triangular configuration for line voltage. The number, size, and spacing of the phase sub-conductors have a minor effect on the gradient, with the gradient increasing as the apparent size of the phase conductor is increased. The steps taken to reduce corona and RIV tend to increase the voltage gradients at ground level. The maximum electric field intensity increases as plant height increases beneath a prototype 1100 kV transmission line. This increase is caused by raising the effective ground plane for the transmission line. The project will involve tests made on the germination rate of seeds and morphological changes at the cellular level. Plants will be grown through several life cycles under different electrical fields to assess effects on pollen tube growth, pollen viability, meiosis, and mitosis. (20 references)

- 0709 ORIENTATION BEHAVIOR OF RING-BILLED GULL CHICKS (LARUS DELAWARENSIS) EXPOSED TO PROJECT SANGUINE'S ELECTRIC AND MAGNETIC FIELDS. (E.) Southern, W. E. (Dep. Biol. Sci., Northern Illinois Univ., DeKalb). *Res. Rep.*, Office of Naval Research, Contract No. N00014-72-A-0050-0002, 32p., 1973.

A study of possible Sanguine impact on avian migrational orientation was conducted during the summer of 1973. Ring-billed Gull chicks were used to determine if the magnetic and electric fields produced by the energized antenna had an effect on their direction finding ability. Experimental trials were conducted with either north-south or east-west antenna energized with 260 or 300 A at 45 or 76 Hz of CW or modulated signal. Trials serving as controls were conducted when the entire system was shut down. All trials were conducted during low intensity disturbances in the geomagnetic field. The 255 controls showed mean headings ranging between 145.93° and 154.28° which are consistent with the headings predicted for the population sampled. Analysis of the 1133 experimental trials conducted with the buried antenna energized did not produce such clear cut results although a detrimental effect was evident. Frequency, amperage, and mode of transmission did not noticeably modify the birds' responses during trials. The AC magnetic field produced by the energized antenna and superimposed on the geomagnetic field is responsible for the recorded disorientation. These effects were recorded at ground level where the Sanguine field was at its maximum intensity. Birds subjected to short term exposure to the Sanguine fields responded similarly to those given larger exposure. It is possible that the fields estimated to occur at even 1000 ft above the operating system may be sufficient to cause disorientation of juvenile Ring-billed Gulls. (13 references)



0710 ELECTRICAL ENHANCEMENT OF HEALING IN COMBAT  
INJURIES TO HARD AND SOFT TISSUES. (E.)

Savara, B. S. (Health Sci. Cent., Univ. Oregon, Portland), R. W. Fields, R. T. Tacke, and M. H. Bartley.  
*Res. Rep.*, U.S. Army Med. Res. Dev. Command, Contract  
No. DADA-17-72-C-2185, 26p., 1974.

Experiments are being conducted to establish quantitative relationships between application of electric current and the reparative process in hard and soft tissue. *In vivo* dog calvarium models were used in conjunction with tetracycline hydrochloride labeling techniques to determine whether the reparative process in hard tissue is enhanced or accelerated. *In vivo* studies of the soft tissue of rats and *in vitro* studies of tissue and cell cultures were conducted to determine the effects of current levels, waveforms, and electrode materials. Dogs (23-35 lb) from a defined genetic pool were utilized. Four circumscribed defects, 4 mm square, were cut through the cortical and spongy bone into the marrow of each parietal bone using a dental handpiece. Electrodes were implanted on each side of the defect and a constant direct current of 0.10, 1.0, or 10  $\mu$ A was applied. Daily physical examinations and weekly hematological and serum chemical evaluations were reported. Tetracycline hydrochloride was administered i.v. (10 mg/kg total body wt) at 1, 3, and 5 wk post operatively. On the 42nd day post operative, the animal was sacrificed and a complete autopsy was performed. All defects of the animals that had received current were in a more advanced state of repair than those of animals that had not received current. Those defects receiving current in the earlier stages (1-3 wk) of the reparative process showed slightly more advanced repairs than those in the later stages (4-6 wk) and controls. In soft tissue repair, observations correspond to the results found in the hard tissue *in vivo*. *In vitro* cell and tissue culture studies of primate fibroblasts grown in suspension and in monolayer cultures showed that cultures receiving 0.1 and 1.0  $\mu$ A direct current exhibit slightly increased cell counts when compared to controls, but no significant change in cell viability was seen. Under microscopic examination of the monolayer culture, an uneven distribution of mitotic figures which are more numerous in the area of the cathode are seen. Cultures receiving 10  $\mu$ A current show a definite decrease in total cell count with no significant difference in the viability count. This work is continuing. (45 references)

## CURRENT RESEARCH

- 0200 INFLUENCES OF VERY WEAK EXTRA-PHOTIC ELECTROMAGNETIC FIELDS. Brown, F. A. (Sch. Arts Sci., Northwestern Univ., Evanston, Ill.).

See CR 0112, Volume II(1), for description of this research. (Renewed 7/75-6/76)

Supporting Agency:U.S. Natl. Sci. Found., Div. Biol. Med. Sci.

- 0201 OCULAR PATHOLOGY FROM ELECTROMAGNETIC RADIATIONS. Fine, B. S.; Hirsch, S. E.; Tso, M. O. (Univ. Assoc. Res. Educ., Bethesda, Md.).

It is known that damage to ocular tissues may occur by exposure to various wavelengths of the EM spectrum. Damage is dependent on the amount of energy absorbed. With development in recent years of a wide variety of sources of powerful EMRs, some of which are, in addition, coherent (i.e., masers and lasers) the potential grows for accidental injury to the eye. This research proposes to evaluate the sequence of morphologic events produced in ocular tissues by such devices in both the visible and invisible portions of the spectrum. Current methods of light and electron microscopy will be applied to these studies. This project consists of two parts: (1) an evaluation of two important regions of the invisible spectrum using (a) an ultraviolet laser to determine effects on cornea, lens, and possibly the retina in short (days, weeks) and medium term (months, year) experiments and (b) determination of the effects of MW radiation on the lens in short, medium and long term experiments, and (2) an evaluation of damage to the primate fovea by coherent visible light using a CW laser (Argon). The proposed studies are currently of great clinical importance in the matter of evaluating the potential for accidental injury and determination of standards of safety. (6/75-5/76)

Supporting Agency:HEW, PHS, FDA.

- 0202 THE EFFECTS OF LOW POWER DENSITY ELECTROMAGNETIC ENERGY ON BIOLOGICAL SYSTEMS. Flanigan, W. F.; Ridgway, S. H. (Biosyst. Res. Dep., U.S. Navy, San Diego, Calif.).

The objective of this project is to study the electrophysiology (i.e., brain wave activity, heart rate) and behavior of reptiles (turtles) exposed to low power density ( $\leq 10 \text{ mW/cm}^2$ ) EMR at a number of frequencies within a range of 0.1 to 10 GHz. Nonmetallic electrodes will be developed to enable both EEGs and ECGs to be recorded from the brain and heart, resp., of acute and chronically implanted animals. All field exposure experiments will be conducted in air. Acutely implanted turtles will be anesthetized or partially anesthetized and restrained. EEGs and ECGs will be simultaneously recorded. Chronically implanted animals will be prepared using a standardized procedure. Each animal will serve as its own control. Baseline recordings prior to any field exposure will be compared with those obtained when

an animal is exposed to EMR. Cumulative effects of recurring field exposure will be investigated by comparing baseline recordings to recovery recordings made between periods of irradiation as well as by comparing subsequent field exposure recordings with prior field exposure recordings. Baseline field exposure recovery recordings will range from a fraction of a second to hours for acute preparations and minutes to days for chronically implanted animals. Electrophysiological techniques will be employed including spectral analyses of EEGs and averaged cortical evoked potentials using a computer of averaged transients to determine sensitivity to EMR. (7/74-6/75)

Supporting Agency:U.S. Dep. Def., Navy.

- 0203 FLUID SHEAR OR MAGNETIC ALIGNMENT OF BLOOD COMPONENTS. Gardner, R. A.; Joist, J. H.; Sutura, S. P.; Barnothy, M. F.; Barothy, J. M. (Sch. Eng. Appl. Sci., Washington Univ., St. Louis, Mo.).

The objective of this project is to identify quantitatively field mechanisms of interaction in blood due to either fluid flow (rate-of-shear) or externally applied fields (electric or magnetic). Two such effects that have been documented recently are the delay of *in vitro* thrombus formation due to either increasing rate of shear in the flow or the application of an external magnetic field. The efforts of this research will be focused on the working hypothesis that the mechanism which results in these effects is the preferential alignment of one or more of the macromolecular participants in the *in vitro* thrombus formation process. Fresh whole blood (wb) or platelet-rich-plasma (prp) from fasted donors will be used to produce coagula under the controlled *in vitro* flow conditions of a modified Chandler rotating loop system. The effects to be studied include the dependence of thrombus-formation time in prp and wb on field strength and rate-of-shear and the dependence of thrombus structure in wb and prp on field strength and rate-of-shear. The reduced sedimentation of erythrocytes in whole blood or single protein solutions in a transverse field will be examined theoretically and experimentally in order to identify orientation effects. Solutions of single blood proteins will be examined using the optical techniques of spectrophotometry, spectropolarimetry and birefringence to quantify their orientation in a transverse magnetic field. (6/75-5/76)

Supporting Agency:HEW, PHS, NIH.

- 0204 DEVELOPMENT OF A HIGH POWER MICROWAVE FOCUSED OVEN. Guidotti, A.; Cheney, D. L.; Costa, E.; Wang, C. (Lab. Preclin. Pharmacol., Natl. Inst. Ment. Health, Bethesda, Md.).

See CR 0079, Volume I(3), for description of this research. (Renewed 7/74-6/75)

Supporting Agency:HEW, PHS, Natl. Inst. Ment. Health

## CURRENT RESEARCH

*Biological Effects Electromagnetic  
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0205 PRE- AND POSTNATAL EFFECTS OF MICROWAVE IRRADIATION. Jensh, R. P.; Brent, R. L.; Weinberg, I.; Vogel, W. (Sch. Med., Thomas Jefferson Univ., Philadelphia, Pa.).

There are three objectives of this investigation. Techniques and instrumentation will be developed further for the determination of exposure and dosimetric parameters at 915 and 2450 MHz, and for the determination of the influence of pulsed exposure, continuous exposure, peak power, and average power (pulsed irradiation). The dosage and monitoring procedures will be refined through polishing of techniques and instrumentation for quantitative measurement of modulated and pulsed transmission of 2450 and 915 MHz and power ranges at or near those currently considered acceptable. The effects of low dose chronic prenatal MW irradiation and (1) embryonic and fetal development in the rat, (2) postnatal development in the rat, (3) reproductive capacity of the rat, and (4) CNS of the exposed adult offspring will be determined. The procedure will include three power ranges at two transmissions and two frequencies (2450 and 915 MHz) and four time periods in the rat pregnancy plus paired controls. (6/75-5/76)

Supporting Agency:HEW, PHS, NIH

0206 VESTIBULO-COCHLEAR EFFECTS OF UHF-MICROWAVE RADIATION. Lebovitz, R. M.; Seaman, R. (Sch. Med., Univ. Texas, Dallas).

This research concerns the experimental examination of the neural activity in the vestibular system of animals subject to acute, cranial MW radiation. This work will proceed initially on mongrel cats and progress to monkeys as techniques are refined. With the animal immobilized in a stereotaxic frame, MW radiation will be applied to the cranium at an incident frequency of 915 MHz, using power densities in the range of 5 to 100 mW/cm<sup>2</sup>. The relevant data include gross field and single cell electrical activity in the vestibular nerve and associated nuclei. Interspike intervals are analyzed by computer for average rate and interval statistics and correlated with the MW radiation. As a control, known but weak cranial acceleration is applied before and during MW exposure to classify the unit and field response pattern. Other controls include vestibular nerve section, intracranial temperature monitoring and histological verification of electrode sites. Particular attention is paid to the suppression of MW induced field artifacts in electrodes and to the calibration of absorbed energy. A secondary aim of this work will be to examine the effects of MW radiation unit activity in the auditory pathway. (5/75-4/76)

Supporting Agency:HEW, PHS, FDA

0207 BIOLOGICAL EFFECTS OF MICROWAVE RADIATION. McAfee, R. D.; Cazenavette, L. L.; Holland, M. G.; Robinette, C. D. (VA Hosp., New Orleans, La.).

In order to determine if MW radiation can produce cataracts in primates, the face and eyes of operantly trained unfettered rhesus monkeys have been irradiated during their operation of a manipulandum. The operant conditioning apparatus has been built and the MW irradiation equipment is in use. Power densities (500 mW/cm<sup>2</sup>) and durations (15-20 min) of x-band pulsed MW irradiation to the face, which produces ocular and skin injury in anesthetized animals, have been found to be readily tolerated by unanesthetized rhesus monkeys for a rewarding drink presented in 0.25 ml increments on a variable schedule (25%). A long term study of possible latent effects of chronic exposure to 9.31 GHz pulsed MW irradiation is in progress with eight experimental and eight control unfettered rhesus monkeys. The original pilot study is being enlarged to a full scale investigation of electronic technicians who may have been exposed to MW radiation. It will be their task to obtain the names and addresses of selected groups of veterans to whom the shadow-graph device will be mailed. The data obtained will be statistically interpreted. (7/75-6/76)

Supporting Agency:U.S. Veterans Adm.

0208 MINIMALLY-INVASIVE STIMULATION WITH IMPLANTED DIODE. Schuder, J. C.; Stoeckle, H.; Almond, C. H.; Stephenson, H. E. (Sch. Med., Univ. Missouri, Columbia).

Electrical stimulation of biological tissues is currently used or under active consideration for use in the treatment of a variety of clinical problems. While the possibility of selective electrical stimulation of a localized region within the body by completely noninvasive means has been postulated on theoretical grounds, such stimulation has yet to be demonstrated experimentally. However, the selective stimulation of a localized region within the body can be achieved by implanting a very small diode at the desired site and then applying a pulsed RF field by means of electrodes or a coil on or near the surface of the body. Reasonably complete theoretical descriptions of the two systems have been derived on the basis of an idealized model in which circular electrodes or the coil are placed on the surface of a semi-infinite homogeneous medium. The direct current component of diode current is related to the power input to the electrode pair or to the coil and to the geometry of the system. The two systems are being currently evaluated for the cardiac pacing of dogs and the study will be extended to cover other stimulation applications. Input power-diode current relationships will be derived for more complex models.

Supporting Agency:HEW, PHS, NIH

0209 MECHANICAL PROPERTIES AND ENERGY PROPAGATION CHARACTERISTICS OF TISSUES. Ware, R.; McCutcheon, E.; Knapp, C.; Bhagat, C. (VA Hosp., Lexington, Ky.).

The objective of this research is to investigate the



correlation of classical mechanical properties of various kinds of human and animal tissue in correlation with the tissue propagation characteristics for US and EM energy. Investigation of transmission spectra of the full range of infrared energy for dog blood and design of US test range and instrumentation systems are already underway. The goal for the first year is to complete design and fabrication of the test range and instrumentation system and to obtain preliminary data using animal (dog and rabbit) tissues. (7/73-6/74)

Supporting Agency: U.S. Veterans Adm.

0210 BIOELECTRIC PHENOMENA CONTROLLING BONE GROWTH. Bassett, C. A.; Pawluk, R. J.; Chokshi, H. R.; Park, I.; Bogoshian, A. (Sch. Med., Columbia Univ., New York, N.Y.).

The objective of this project is to develop a highly effective surgically noninvasive method to increase the rate and frequency of fracture repair. Capacitively coupled electric and inductively coupled EM fields already have been shown to have the ability to influence osteogenesis and other biological processes. The coupling efficiency of present fields, however, is not capable of provoking osteogenic stimulation of a magnitude already shown possible with a potent biochemical osteogenic factor. Since the biological system has a demonstrated capacity to respond on a scale heretofore thought impossible, it appears important to develop electric perturbations which can trigger responses of this magnitude. As an initial step to increase the effectiveness of these modalities, an attempt will be made to study mechanisms by which pulsing electric and EM fields interact with non-excitable cells to alter their behavior. Primary emphasis is to be focused on effects at the plasma membrane-glycocalyx interface and the capacity of this structure to complex or release cations such as  $\text{Ca}^{+2}$  and  $\text{K}^{+1}$ . Results will be correlated with altered patterns and rates of collagen and DNA synthesis by connective tissue cells *in vitro*. The relationships established by these studies will be used to screen pulse characteristics, such as amplitude frequency, shape, and width, for maximal perturbation of cell function. Data arising from these basic studies will be applied in fracture and pseudarthrosis models in animals. (12/74-3/75)

Supporting Agency: HEW, PHS, NIH

0211 ACCELERATION OF FRACTURE HEALING BY ELECTRICAL FIELDS. Brighton, C. T.; Friedenberg, Z. B.; Black, J.; Korostoff, E.; Heppenstall, R. B. (Sch. Med., Univ. Pennsylvania, Philadelphia).

See CR 0134, Volume II(2), for description of this research. (Renewed 9/75-8/76)

Supporting Agency: HEW, PHS, NIH

0212 EFFECTS OF LOW INTENSITY MICROWAVE RADIATION ON MAMMALIAN SERUM PROTEINS. Cleary, S. F.; Berry, E. R. (Sch. Med., Virginia Commonw. Univ., Richmond).

See CR 0136, Volume II(2), for preliminary description of this research. This ongoing project is designed to synthesize *cis* and *trans* isomers of  $\beta$ -mercaptoethylamine and  $\gamma$ -mercaptophenylamine for studies to determine their radio protective properties. Careful studies have been made to determine modes of synthesis of the proposed compounds. The general approach will be to follow the routes of synthesis so as to make sufficient quantities of the compounds for testing. (Renewed 7/75-6/76)

Supporting Agency: U.S. Dep. Def., Army

0213 BEHAVIORAL AND BIOLOGICAL EFFECTS OF RESONANT ELECTROMAGNETIC POWER ABSORPTION IN RATS. Gandhi, O. P.; Johnson, C. C. (Sch. Eng., Univ. Utah, Salt Lake City).

See CR 0080, Volume I(3) and CR 0148, Volume II(2), for descriptions of this research. (Renewed 7/75-6/76)

Supporting Agency: U.S. Dep. Def., Army

0214 MECHANISMS OF MICROWAVE INTERACTION WITH HUMAN AUDITORY SYSTEMS. Lin, J. C.; Yu, F. T. (Wayne State Univ., Detroit, Mich.).

This research will investigate, through theory and experiment, the mechanism of interaction of pulsed MWs with living tissues. This involves analytic studies of the stress and forces induced by the incident MW energy, optical measurement of vibrations in models of human and animal heads exposed to pulsed MWs, and theoretical and experimental investigations of the frequency behavior of the induced vibrations which may be used to isolate the precise mechanism involved in the auditory phenomenon. The results of this research will advance the existing knowledge on the quantitative effects of MW energy on living organisms and provide some urgently needed scientific information in determining human tolerance to MW radiation. (8/75-7/76)

Supporting Agency: Natl. Sci. Found., Div. Eng

0215 ANALYSIS AND PREPARATIONS OF AVAILABLE WORLD LITERATURE ON BIOLOGICAL EFFECTS OF NONIONIZING ELECTROMAGNETIC RADIATION. Lindberg, R.; Larrimore, J. (Mead Corp., Dayton, Ohio).

See CR 0103, Volume II(1), for description of this research. (Renewed 7/75-6/76)

Supporting Agency: Office Telecomm. Pol.

CURRENT RESEARCH

- 0216 THE ROLE OF CYCLIC AMP AND CYCLIC GMP IN  
THE CENTRAL NERVOUS SYSTEM. Lust, W. D.;  
Passonneau, J. V.; Kupperberg, H. J.; Yonekawa, W. D.  
(HEW, PHS, NIH, Bethesda, Md.).

The reactions of cyclic AMP and cyclic GMP to induce alterations experimentally in brain metabolism were investigated *in vivo*. Cyclic GMP in the cerebellum increased following electroconvulsive shock (ECS) and after the administration of either CNS stimulants or convulsants. The levels of cyclic GMP were decreased following the injection of a number of CNS depressants and anti-convulsants. While cyclic AMP also increased following ECS, this cyclic nucleotide is pharmacologically unresponsive. Most of the anti-convulsants tested to date decreased the cyclic GMP levels by greater than 50%. The relationship of cerebellar cyclic GMP to both electrically and chemically induced seizures is currently being investigated. (7/74-6/75)

Supporting Agency:HEW, PHS, NIH

- 0217 INVESTIGATION OF OCULAR EFFECTS OF CHRONIC  
EXPOSURE OF PRIMATES TO MICROWAVE RADIATION  
AT 2.45 GHZ. Polson, P. (Stanford Res. Inst., Menlo  
Park, Calif.).

See CR 0102, Volume II(1), for description of this research. (Renewed 7/75-6/76)

Supporting Agency:U.S. Dep. Def., Army

- 0218 BIOLOGICAL EFFECTS AND HAZARDS OF MICRO-  
WAVE RADIATION. Hunt, E. L.; Larsen,  
L. E.; Jacobi, J. H. (Walter Reed Army Inst. Res.,  
Washington, D.C.).

See CR 0117, Volume II(1), for description of this research. (Renewed 7/75-6/76).

Supporting Agency:U.S. Dep. Def., Army

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